Biofuels: ethical issues

NUFFIELD COUNCIL ON BIOETHICS

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Biofuels: ethical issues

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The terms of reference of the Council are:

1. to identify and define ethical questions raised by recent advances in biological and medical research in order to respond to, and to anticipate, public concerns;

2. to make arrangements for examining and reporting on such questions with a view to promoting public understanding and discussion; this may lead, where needed, to the formulation of new guidelines by the appropriate regulatory or other body;

3. in the light of the outcome of its work, to publish reports; and to make representations, as the Council may judge appropriate.

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Acknowledgments

The Council would like to thank the members of the Working Party for the considerable time, hard work, enthusiasm and expertise that they contributed to this report.

A Council project goes through several stages. A Working Party of experts is set up, which in this case met ten times over 14 months. The project usually starts with a three-month public consultation and other evidence and opinion gathering activities, such as meetings with stakeholders. Following in-depth discussions by the Working Party, a draft report is written and then peer-reviewed by experts in the field. The report is published after final approval from members of Council.

We are indebted to all those who attended and contributed to fact-finding meetings (see Appendix 1); to those who responded to our consultation (see Appendix 2); and to the peer reviewers who commented on an earlier version of this report: Professor Harry de Gorter, Professor Mark Harvey, Professor Tim Hayward, Dr Angela Karp, Professor John O'Neill, Professor Chris Somerville, Mr Geoff Tansey, and Professor Henrik Wenzel.

The Council and the Working Party would also like to thank those who provided invaluable advice and input on specific areas of the report at various stages, including Professor James Smith, Dr Jon Finch, Dr Ben Richardson, Mr Greg Archer, Professor Paul Freemont, Dr Barney Dickson, Dr Nathalie Doswald, and Dr Val Kapos.

Foreword

Public and industrial investment in biofuels began to accelerate in the 1990s both in the US and Europe, stimulated in part by recognition of the challenges raised by human-induced climate change and the need to reduce our dependence on fossil fuels. But this is also part of a broader biotechnology-based vision for the 21st century of a new global 'green economy' that, to quote the Organisation for Economic Co-operation and Development, is "stronger, cleaner and fairer".

However, as the Nuffield Council on Bioethics appreciated, this positive vision has a downside and early attempts to increase global production of biofuels have had serious negative impacts on the livelihoods of some of those who cultivate the land, on the sustainability of cultivation systems and on biodiversity. The starting point for this report was the widely held expectation that new technology-based approaches to biofuels development would begin to address these negative impacts.

The Working Party's early meetings involved a fundamental reassessment of the task we had set ourselves. We recognised that the proposed new approaches are unlikely to solve all the problems inherent in current biofuels developments and that current approaches will remain dominant in the immediate future; we also recognised our very limited abilities to foresee the outcomes of current investments in basic research on biofuels. We also became aware of the technical challenges involved in scaling up biofuels production, from whatever source, to a point where it can have a significant impact on the global use of fossil fuels.

Rather than the planned "before and after new biofuels" approach, this report considers the ethical issues raised by both current and potential future approaches to biofuels development, seeing this as an overlapping continuum, and attempting to influence the trajectory of biofuels development to meet the ethical principles set out in our framework.

We also realised the complexity of the balancing act we are intent on achieving. A continuing concern has been our desire to find ways to facilitate the development of new biotechnologies with the potential either to deliver societal benefits more effectively than before or to mitigate the negative impacts of current biofuels approaches. In attempting to ensure that innovative biotechnology approaches do deliver societal as well as technological benefits, we do not want to place hurdles in their path that will prevent their development altogether. Likewise, we do not want to impose inequitable burdens on biofuels development that are not applied to other similar areas of human activity such as agriculture.

Such decisions involve balancing one set of needs against another and our concern throughout our discussions has been to protect the needs of the most vulnerable, particularly in the developing world. This would include avoiding placing restrictions on their use of biofuels that would prevent them from taking up locally important opportunities because of internationally imposed restrictions, however well intentioned. Applying bioethical principles to the cause of fairness and justice in the world, recognising that technological progress will be an important part of delivering these aims and being open to considering how these aims can best be reconciled have been our guiding motivations.

We have focused on policy, legislation and governance as the key to this balancing of ethical principles, technological opportunities and a diverse array of sometimes-conflicting human needs, in the context of uncertainty over which new approaches to biofuels will actually be feasible and over what timescale.

Exhorting people to make lifestyle changes will, of course, continue to be one approach to overall reduction of greenhouse gas emissions. However, this and other non-fuel-based power sources such as wind, wave and solar energy will not be sufficient to reduce global dependence on fossil fuels for the foreseeable future. We will need new sources of liquid fuels and new ways of producing current biofuels more efficiently, and advanced biotechnology, including genetic modification, could be an important part of the tool kit to help deliver on these needs. Precautionary safeguards have already been built in to the development of advanced biotechnologies and this will not present any new hazards. Indeed, it is important that precautionary approaches are implemented in a balanced and equitable way – we should be as precautionary about the risks of doing nothing as we are about the risks of developing new technologies.

Effective policy needs to be underpinned by good evidence and we have been committed to maintaining high standards for the evidence that has contributed to our conclusions. Over the course of the project we found that in some areas, for example indirect land use change, the sheer complexity of the issues can mean that different, but equally valid, approaches lead to different outcomes from modelling analyses. In other cases, data and models are consciously used as weapons of argument in promoting the interests and values that are part of political power plays, with scant attention to the validity of the evidence on which they are based. In the context of biotechnology, this arises most often in ideologically motivated debates about biotechnology-based solutions to societal problems. As Arthur Miller has noted:[1] "Evidence…is effort; leaping to conclusions is a wonderful pleasure" – the Working Party and Council staff have denied themselves this particular source of enjoyment.

The Council announced its decision to work on new biofuels-related developments in the immediate aftermath of the United Nations Climate Change Conference in Copenhagen in 2009, and the topic of biofuels has been the subject of a steady stream of media attention since then. As this document is on the brink of going to press, the European Commission has published its report[2] on indirect land use change related to biofuels and bioliquids, announcing that there will be an impact assessment to decide on future policy actions. Policies around biofuels development are likely to continue to be in a state of flux for some time and we hope this report will provide an important contribution to ensuring that policy decisions, nationally and internationally, are made in the full awareness of their ethical implications.

My appreciation of the contributions of the Working Party and of Council staff to the preparation of the report extends well beyond a routine acknowledgement. Our discussions have been stimulating and enjoyable and the openness of all members to accommodating the views of others has been, in my experience, unusual. Most of all we are indebted to Council members and staff, particularly Dr Alena Buyx, Varsha Jagadesham, Catherine Joynson and Sarah Bougourd, for their hard work, endless patience and good humour and particularly their utmost professionalism.

Joyce Tait

1 Miller A (2000) *The Crucible in history: and other essays* (London: Methuen Publishing), p47.
2 European Commission (2010) *Report from the Commission on indirect land-use change related to biofuels and bioliquids*, available at: http://ec.europa.eu/energy/renewables/biofuels/land_use_change_en.htm.

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Terms of reference

1. To review:

   a advances in the development of future generation biofuels, including the use of advanced plant breeding strategies, genetic modification and synthetic biology;

   b the potential of these advances to address climate change mitigation and energy needs and to contribute to economic development.

2. To identify and consider both the advantages and benefits, as well as the ethical, social, legal and economic implications of the development of such future generation biofuels, including:

   a issues of environmental sustainability and protection;

   b impact on food security, particularly for the poor and vulnerable;

   c implications for the rights of workers and farmers in developing countries, including labour and land rights, and health effects;

   d issues surrounding land use for biofuels production;

   e implications for future generations;

   f implications in relation to intellectual property;

   g issues surrounding public acceptance of biofuels;

   h governance of future generation biofuels and related policy issues.

3. To consider the development and implementation of policies, legislation and governance that could promote the safe development and use of future generation biofuels.

4. To draft a report and make recommendations.

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Summary and recommendations

Introduction and overview

1. Biofuels are not a new technology. Rudolf Diesel ran an engine on peanut oil at the World's Fair in Paris in 1900, and liquid fuels made from sources such as food crops have been researched for more than a century. For most of that time, interest in biofuels was confined to rather specialist research projects, largely unnoticed by members of the public (with the exception of Brazil). However, towards the end of the 20th century, a number of challenges to the modern way of life combined to bring biofuels to national and international attention (discussed in Chapter 1). Increasing worries over energy security in the face of growing demand, dwindling supplies of oil, and international conflicts and wars drove countries dependent on energy imports to look for alternative, home-grown sources. Interest in biofuels further intensified with the search for new opportunities for economic development, especially in agriculture. This was particularly relevant in emerging economies such as India and China; however, creating new jobs and a new industry are also attractive prospects in the developed world, where many established sectors such as agriculture and manufacturing are increasingly precarious. And, most recently, the growing awareness of the dangers of global climate change reinforced the challenge to find alternatives to fossil fuels as the dominant form of energy.

2. Biofuels appeared, therefore, to promise a great deal; indeed, the expectation of some was that they would solve these great challenges all at once: i.e. provide a new source of income for farmers and revenue from 'clean' technology, as well as renewable – and therefore endless – sources of fuel, leading to far less greenhouse gas (GHG) emissions than fossil fuels. Though not a silver bullet, they were certainly regarded by some as a 'green' answer to many problems. Even the former US President, George W Bush, not known to be a strong champion of green issues, was convinced of the potential of biofuels and promised his fellow Americans that: "the best way and the fastest way to replace oil…is to expand the use of ethanol…. It's good for economic development for rural America….Ethanol is good for the environment. I keep emphasizing that we can be good stewards of our environment and at the same time continue with our economic expansion."[3]

3. Successive governments recognised the potential of biofuels and in the last decade a number of policy and regulatory mechanisms were implemented that made the introduction and blending of biofuels mandatory (Chapter 1). The two main biofuels, bioethanol (to blend with petrol) made from, for example, corn, wheat or sugar cane, and biodiesel (to blend with diesel) made from palm oil or rapeseed oil, were produced at progressively industrial levels. While still making up only a small fraction of fuel and energy use worldwide, biofuels production increased significantly and very rapidly. For example, between 1998 and 2009, the production of biodiesel in the European Union (EU) increased more than ten-fold.[4] Currently, biofuels make up more than three per cent of UK road transport fuel. Worldwide, it is expected that by 2030 biofuels will account for seven per cent of road transport fuel.[5]

4. While excitement over biofuels was still in full swing, important problems with their large-scale production began to emerge (discussed in Chapter 2). The claims that biofuels produce significantly lower GHG emissions compared with fossil fuels were contested. Concerns were also raised over the competition that biofuels pose to food production, and their consequent effects on food security and food prices. Moreover, many worried about infringements of the

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[3] The Washington Post (25 Apr 2006) *Bush delivers speech on renewable fuel sources*, available at: http://www.washingtonpost.com/wp-dyn/content/article/2006/04/25/AR2006042500762.html.

[4] European Biodiesel Board (2009) *The EU biodiesel industry*, available at: http://www.ebb-eu.org/stats.php.

[5] International Energy Agency (2007) *Renewables in global energy supply: an IEA factsheet*, available at: http://www.iea.org/papers/2006/renewable_factsheet.pdf, p15.

rights of farmers, farm workers and land holders, particularly in vulnerable populations in the developing world. There were also reports of severe environmental consequences, including pollution and the loss of biodiversity, for example through the destruction of rainforest, following large-scale biofuels production. In addition to possible direct land use change (dLUC), biofuels were implicated in the 'knock-on effect' of indirect land use change (iLUC), where the displacement of other activities also led to deforestation and depletion of scarce water resources.

5. These negative effects are still contested (Chapter 2) but there have already been major political and social repercussions, with protests against biofuels which, in some instances, have been as extreme as violence in the streets. In the case of some commentators and activists, the backlash against the use of biofuels has been severe. The technology heralded as a potential all-round solution to many problems has been accused of harmful impacts ranging from near extinction of the orang-utan to pushing the poorest even further into poverty, thus "driving a global human tragedy".[6]

6. The demand for biofuels created by legislation and regulation has prompted research into more efficient sources of biomass and more efficient production and conversion techniques. These developments are often known as 'second generation' biofuels (the established biofuels are, in contrast, now often called 'first generation' biofuels). The goals of this research are to provide biomass sources – feedstocks – that: i) do not compete with food; ii) have a high energy yield with low inputs of water, land and fertiliser etc.; iii) do not negatively affect the environment or local populations; and iv) can be produced in sufficient quantities to allow economically viable biofuels production. A diverse and active field of research trying to meet these goals is rapidly emerging. Among the most promising candidates so far are those biofuels made from wastes and energy crops using full lignocellulosic conversion and, more speculatively, biofuels made from algae (discussed in Chapter 3).

7. At present, it is almost impossible to predict exactly whether a technology will emerge as a successful biofuels pathway that avoids causing harmful consequences. What can be said with confidence is that the lessons learned from the problems of established biofuels must be integral in the development of new ones in order not to repeat the mistakes of the past. Meanwhile, it is clear that established biofuels will continue to play a role while new products emerge, but mechanisms to mitigate their negative effects are imperative.

8. What this report seeks to do, therefore, is to provide a framework of evaluation on the basis of which more ethical production of current biofuels and the emerging biofuels production systems can be established. In Chapters 4, 5 and 6, we offer such an ethical framework and use it to point out where current policy can be improved. We also make recommendations regarding the direction of future policy development. While taking a necessarily global perspective, we apply specific focus in many instances to the EU, and particularly to the UK.

Chapter 1: Why biofuels? Drivers for biofuels production

9. In this chapter, we describe the main drivers of recent biofuels production. By the end of the 20th century, governments and policy makers around the world faced three key issues: i) (renewed) worries about energy security; ii) commitment to economic development, including the creation and sustaining of jobs, particularly in agriculture; and iii) the need to mitigate global climate change and achieve lower GHG emissions.

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6 The Guardian (15 Feb 2010) *EU biofuels significantly harming food production in developing countries*, available at: http://www.guardian.co.uk/environment/2010/feb/15/biofuels-food-production-developing-countries.

Energy security (paragraphs 1.7–1.22)

10. Energy security is: "the uninterrupted physical availability of energy products on the market, at a price which is affordable for all consumers (private and industrial)".[7] Threats to energy security come in many forms. Some can disrupt the provision of energy to consumers and businesses (e.g. through limited availability of fuel), while others affect the price of energy (e.g. price spikes as a result of geopolitical tensions and war). Biofuels contribute to energy security by increasing the diversity of supply choices and introducing a component of supply that is not necessarily import dependent (some biofuels can be produced domestically in the UK). In addition, biofuels that are locally produced are less susceptible to some threats to energy security, although extreme weather events and terrorist attacks on infrastructure can still affect them.

Economic development (paragraphs 1.23–1.29)

11. Patterns of industrialisation have to date been energy intensive, and this trend continues. Total world energy consumption has been predicted to increase by 49 per cent between 2007 and 2035. This is mainly attributed to increased demand in developing countries that are not members of the Organisation for Economic Co-operation and Development (OECD). In these countries, energy consumption is forecast to increase by 84 per cent, compared with an increase of a comparatively modest 14 per cent in OECD countries.[8] Fuel for transport, i.e. cars, aviation and shipping, makes up almost one-third of total world delivered energy consumption.[9] In addition to the pursuit to meet this rising demand, there is the expectation that investment in biofuels will lead to other significant benefits in economic development, including the creation of new jobs and new areas of income for farmers. An early powerful incentive for biofuels in the US was significant agricultural overproduction, which led to enthusiasm to use food crops for biofuels. Biofuels production might also be a very attractive prospect in developing countries, where a large proportion of the population is engaged in agriculture, and where biofuels might provide a local energy source in energy-deprived areas. As for the UK, new biofuels might present a number of opportunities for economic development of rural areas, offering new avenues for business and farmers, while creating 'green collar' jobs along the way.

Climate change (paragraphs 1.30–1.39)

12. Most climate scientists have concluded that global climate change will have severe social, economic and environmental effects, and the issue has entered public debates and popular culture. International policy reflects the consensus to lower GHG emissions, while at the same time highlighting the challenges of achieving binding transnational agreements. The Kyoto Protocol of 1992 commits industrialised countries to reduce their GHG emissions by at least 5 per cent below 1990 levels by 2012,[10] but further policy, following the Copenhagen Summit in 2009, is still being negotiated. Despite some progress at the most recent Climate Conference in Cancun, Mexico, in 2010, agreement on a legally binding document that goes beyond the Kyoto Protocol has not yet been reached. The UK currently has one of the most ambitious national climate change programmes in the world. The Climate Change Act 2008 demands an 80 per cent cut overall in six GHGs by 2050, relative to 1990 levels.[11] The EU has committed to the "20-20-20" goals, i.e. a reduction in EU GHG emissions of at least 20 per cent below 1990 levels; that 20

7 European Commission (2000) *Green Paper: towards a European strategy for the security of energy supply,* available at: http://ec.europa.eu/energy/green-paper-energy-supply/doc/green_paper_energy_supply_en.pdf, p4.
8 US Energy Information Administration (2010) *International energy outlook 2010 – highlights*, available at: http://www.eia.doe.gov/oiaf/ieo/highlights.html.
9 US Energy Information Administration (2010) *International energy outlook 2010*, available at: http://www.eia.doe.gov/oiaf/ieo/world.html.
10 Kyoto Protocol to the United Nations Framework Convention on Climate Change 1998, art 3.1.
11 s1(1) Climate Change Act 2008.

per cent of EU energy consumption is to come from renewable resources; and a 20 per cent reduction in primary energy use compared with projected levels, all by 2020.[12]

Current European and UK biofuels policy (paragraphs 1.40–1.44)

13. As well as more general policies on reducing GHG emissions and improving energy security, there are a number of European and UK policies which specifically promote the use of biofuels. The European Commission (EC) passed the Renewable Energy Directive (RED) in 2009,[13] which effectively established that biofuels should account for a minimum of 10 per cent of transport petrol and diesel by 2020. The Fuel Quality Directive 2009 also requires Member States to reduce life cycle GHG emissions of transport fuels by 6 per cent by 2020 – a move which has indirectly affected biofuels markets.[14] The UK's Renewable Transport Fuel Obligations (RTFO) (Amendment) Order mandates that 5 per cent of total transport fuel should originate from renewable sources by 2013,[15] and is in accord with RED.

Chapter 2: How did we get here? The story of biofuels

14. Three case studies illustrate the development of current commercially established biofuels in three different countries: bioethanol from corn in the US; bioethanol from sugar cane in Brazil; and biodiesel from palm oil in Malaysia. They do not represent all biofuels production nor all the issues associated with current biofuels. However, these case studies, which include the two biggest producers of biofuels in the world (the US and Brazil), vividly demonstrate some of the main issues that have emerged from large-scale production of biofuels, providing important material for the ethical analysis of biofuels undertaken later in the report.

Case study I: Bioethanol from corn in the US (paragraphs 2.9–2.19)

15. The US is the world's largest bioethanol producer: in 2009, it produced an estimated 40 billion litres of ethanol,[16] mainly derived from corn. The main motivations for biofuels production were economic as well as finding a source of octane and using surplus agricultural production; however, worries over energy security following the oil crisis in the early 1970s played an important role as well. Domestic legislation and policy have in recent years created a favourable environment for the US corn-based bioethanol industry and production has been increasing rapidly.

16. As the industry grew, the production of bioethanol in the US was blamed for increasing the price of corn and other grains by diverting cereal from food uses. The widely publicised 'tortilla riots' in Mexico during late 2006 and early 2007 are one example. Whether these attributions are correct and US biofuels production (and production from other countries) can be blamed for harming food security is currently the subject of fierce debate. Put briefly, biofuels and in particular US corn bioethanol appear to be one contributing factor to changing food commodity prices, which can affect vulnerable countries and populations in particular. However, there are several other factors that also play important roles in destabilising food prices. Blaming food price spikes on biofuels production alone – as is often expressed in the 'food versus fuel' debate – is too

[12] European Commission (2010) *The EU climate and energy package*, available at: http://ec.europa.eu/environment/climat/climate_action.htm.

[13] Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16, art 3.4, commonly referred to as the Renewable Energy Directive.

[14] Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC [2009] OJ L140/88, art 7(a).

[15] Art 4 of The Renewable Transport Fuel Obligations Order 2007 amended by The Renewable Transport Fuel Obligations (Amendment) Order 2009. This could also include other renewable sources, for example electric vehicles powered by electricity from renewable sources such as solar or wind.

[16] Renewable Fuels Association (2010) *Climate of opportunity: 2010 ethanol industry outlook*, available at: http://ethanolrfa.org/page/-/objects/pdf/outlook/RFAoutlook2010_fin.pdf?nocdn=1, p6.

simplistic. That said, there is clearly the potential for more serious effects on food security as biofuels production increases.

17. One of the most contentious issues that arose from evaluations of US corn bioethanol is the debate around iLUC. The concept of iLUC is based on the assumption that growing biofuels crops on existing agricultural land results in new cultivation of food and other crops elsewhere to make up the shortfall in their production. This requires the conversion of land elsewhere in the world to agricultural use. Such iLUC, if it involves the destruction of carbon stocks in grassland, forest/woodland, peatland or wetlands, results in the release of substantial GHG emissions. However, the calculation of both these emissions and the attribution of land use change are extremely difficult and fraught with uncertainty. While some report that production of corn-based bioethanol overall produces more GHG emissions than fossil fuels, other studies cite far more favourable results. Indirect LUC has by now been largely recognised as relevant in principle, but how it should be calculated and dealt with is still a matter of much debate which has yet to be resolved.

Case study II: Bioethanol from sugar cane in Brazil (paragraphs 2.20–2.33)

18. Bioethanol production from sugar cane in Brazil, one of the longest standing biofuels programmes, has been described as the most successful example of producing and using biofuels on a large scale. In 1975, the Brazilian government launched the national alcohol programme 'PróÁlcool' (Programa Nacional do Álcool). The intention was to phase out fossil fuels and to replace them with bioethanol made from sugar cane. The uptake rate of bioethanol in Brazil is unparalleled compared with anywhere else in the world.

19. However, Brazilian sugar cane ethanol production has been criticised for its negative environmental effects, for example caused by field burning and water use, and in particular deforestation. Some say that rainforests and other environmentally valuable land has been and will increasingly be cleared for sugar cane production, and deforestation in the Cerrado and the Amazon has been linked to an increased area of sugar cane plantation elsewhere in Brazil. The degree of causation is unclear. Expansion of agriculture into areas of high biodiversity is neither an inevitable consequence of nor necessarily due to increased biofuels production. However, rapid scaling up of production in response to increasing worldwide interest in biofuels may act as an incentive to expand production into valuable wildlife habitats. To avoid the destruction of valuable forestland and in response to international criticism, in September 2009 the Brazilian Government set up countrywide agro-ecological land use zoning (ZAE Cana) to restrict sugar cane growth in or near environmentally sensitive areas.

20. Brazil has also been accused in the past of not tracking breaches of workers' rights. There have been reports of unhealthy working conditions and even deaths from overwork during sugar cane cutting. Wages are low, and cutters are often paid by the amount they produce, encouraging overworking. There is also informal child labour and, even though Brazil has strict labour laws, enforcement is weak. On the other hand, many sugar cane mills in the ethanol production sector now maintain schools, nursery centres and day care units, as well as some medical, dental, pharmaceutical, sanitation, and educational services for sugar cane workers.

Case study III: Biodiesel from palm oil in Malaysia (paragraphs 2.34–2.42)

21. Malaysia is the second largest producer of palm oil in the world (after Indonesia). In 2009, it produced approximately 17.6 million tonnes of crude palm oil.[17] The main motivations for biofuels production were economic and agricultural development and energy security. The Malaysian

[17] Malaysian Palm Oil Board (2009) *Production of crude palm oil for the month of December 2009: Jan – Dec total*, available at: http://econ.mpob.gov.my/stat/web_report1.php?val=200904.

Government has introduced policies and legislation to encourage the production and use of palm oil-based biodiesel. In 2008, Malaysia produced approximately 1.3 million litres of biofuel, and production is expected to increase steeply.

22. The rapid expansion of Malaysian palm oil biodiesel has led to worries over the conversion of forests to oil palm plantations that might have detrimental impacts on South-East Asia's biodiversity. The potential impacts of lost forestland and biodiversity in this region are particularly significant given that, by some estimates, South-East Asia contains 11 per cent of the world's remaining tropical forests which are home to many rare species, and reports have warned of the extinction of, for example, the orang-utan of Borneo. Moreover, the conversion of lowland tropical rainforest would result in significant GHG emissions. Malaysia also faces issues of illegal logging, which at current scales poses significant threats to the environment and local communities.

23. There have also been accusations of so-called 'land grabs' by palm oil producers. Companies have been accused of clearing large areas of land and displacing indigenous tribes who, despite often not having official title to the land, may exercise Native Customary Rights because they have lived there for generations and depend on the land for their livelihood.

Consequences for policy (paragraphs 2.43–2.47)

24. Some policy changes have occurred following reports about the US, Brazil, Malaysia and other countries detailing the negative consequences of large-scale biofuels production. For example, the UK *Gallagher Review* called for further investigation of the issue of iLUC and suggested postponing a higher mandated percentage of biofuels in the UK by a few years.[18] The RED now includes several social and environmental standards. In view of this recent history of biofuels production, there is an urgent need to look at the issues openly, in the light of new technical developments, and with a clear statement of principles governing any future implementation and expansion.

Chapter 3: New biofuels – scientific developments

25. The development of new biofuels technology is a rapidly growing field, focussing on the use of abundant biomass feedstocks that: can be produced without harm to the environment or local populations; are in minimal competition with food production; need minimal input of resources such as land and water; can be processed efficiently to yield high-quality liquid biofuels; and are deliverable in sufficient quantities. Various biomass feedstocks have been proposed, including lignocellulosic biofuels and algae.

Lignocellulosic biofuels (paragraphs 3.5–3.30)

26. In the production of lignocellulosic biofuels, all of the plant biomass is used, including the lignin and the cellulose, instead of just the sugary, starchy or oily parts (such as in biofuels from food crops). Because of this, lignocellulosic biofuels yield more energy per unit mass of feedstock; however, they also require far more sophisticated processing. Agricultural waste can be processed into biofuels, making some crops effectively 'dual-use', i.e. producing food as well as fuel. The supply of this source of fuel is, however, limited. For this reason, a lot of activity surrounds dedicated biofuels crops, such as willow, miscanthus and switchgrass, which are nutrient-efficient and, once established, require no tillage, thus preserving soils. They also have significant genetic diversity and therefore there is potential to improve their characteristics such as yield, water use and pest and frost resistance using advanced plant breeding strategies (APBS). An important goal for dedicated biomass crops is to identify or develop variants that can grow on land unsuitable for food cultivation and which require little in terms of water and other

[18] Renewable Fuels Agency (2008) *The Gallagher Review of the indirect effects of biofuels production*, available at: http://www.renewablefuelsagency.gov.uk/sites/renewablefuelsagency.gov.uk/files/_documents/Report_of_the_Gallagher_review.pdf.

inputs, such as fertiliser. Nevertheless, the danger still exists that agricultural resources – mainly land – are diverted away from food production, and that the overall demand for these resources intensifies, resulting in significant GHG emissions due to iLUC.

Algae (paragraphs 3.31–3.40)

27. Algae are a very diverse group of aqueous photosynthetic organisms that are being investigated for their potential to be processed into biofuels. Some algae produce an array of oil-related compounds that can be used directly to produce biodiesel, thus avoiding the technical challenges of converting lignocellulosic biomass to biofuels. They can use wastewater as a source of nutrients and waste combustion gas as a source of carbon dioxide. They are also expected (with added carbon dioxide) to produce a higher biomass yield per unit area than crop plants. Depending on where and how they are cultivated, algae could minimise or avoid competition with food production for land and nutrients, and using algae that can be grown in the sea might reduce the need for freshwater. Finally, algae are compatible with processing in biorefineries, producing a variety of fuels and valuable co-products such as vitamins. However, currently, the production of algal biofuels is mostly experimental and, mainly owing to costly harvesting and processing, very expensive.

28. Lignocellulosic feedstocks and algae both show significant potential for improvement in the production of biofuels. Advances in using modern biotechnology illustrate the options available to avoid the problematic consequences of current biofuels, in particular regarding land use, environmental impacts and competition with food. However, just like established biofuels, new approaches have to avoid harmful effects, and the next chapter offers an ethical framework that can be used in decision making about which path to pursue.

Chapter 4: Ethical framework

29. As shown, current biofuels give rise to a number of concerns, and the new approaches to biofuels development and production are also likely to be controversial. Chapter 4 proposes a number of moral values for considering both current and new biofuels. These key moral values are both commonly shared and of relevance to current and future biofuels. Together, and through their confluence, they constitute a moral framework enabling us to construct strong Ethical Principles (set out in paragraph 35 below) that should enjoy widespread support.

Human rights (paragraphs 4.8–4.13)

30. International human rights establish a moral minimum below which the treatment of people should not fall. Human rights are universally enjoyed by *all* human beings, no matter the state or nation to which they belong; they capture a universal element of the concept of global justice. Biofuels clearly have international implications, and states have a duty to design regulatory frameworks to ensure that the development of biofuels does not violate those human rights which are essential conditions for at least a decent opportunity for human flourishing, giving equal weight to the human rights of their citizens and non-citizens. Biofuels production breaches basic human rights when it endangers local food security or displaces local populations from the land they depend on for their daily subsistence. Similarly, biofuels production becomes a human rights issue when it threatens or destroys ecosystems and natural resources that are critical to the health and subsistence of people. Invoking human rights to support our Ethical Principles does not mean that we adopt an exclusively human rights-based approach to the evaluation of biofuels technology. However, mainly through their legal dimension, human rights serve very well to justify some minimum moral conditions which must be met and which are set out mainly under Principle 1.

Solidarity and the common good (paragraphs 4.14–4.17)

31. Solidarity focuses on the importance of protecting individuals as members of groups or populations. It is the idea that we are all 'fellow travellers' and that we have duties to support and help each other and, in particular, those who cannot readily support themselves. In the context of biofuels, the value of solidarity directs ethical attention to the most vulnerable people within societies, reminding us that we have a 'shared humanity', a 'shared life' and that those who are most vulnerable should be given special attention. For biofuels development, the value of solidarity thus requires countries or companies to ensure just reward, that benefits are shared equitably and that burdens are not laid upon the most vulnerable in society (see Principles 4 and 5).

32. Common good arguments capture the idea that there are some goods that we believe all – including future generations – should share equitably, in whichever society they live. A common good is more than the sum of individual benefits. Common goods are often goods of global relevance, such as the protection of the climate or important ecosystem services. This provides justification for several Principles (in particular Principles 2 and 3). A common good perspective also underlines the urgency of the debate about biofuels. Although there are justifiable criticisms of some of the consequences of biofuels and fears about the possible implications of new ones, the status quo involving increasing use of fossil fuels does not itself accord with a common good perspective. Doing nothing can sometimes amount to doing something extremely damaging, and finding other ways of securing essential energy needs might be required to realise the common good. This is reflected in Principle 6.

Sustainability, stewardship and intergenerational justice (paragraphs 4.18–4.21)

33. Stewardship and sustainability generate obligations to those elements of the natural world which are not of immediate material benefit to people, particularly where the interests of future generations are involved. Sustainability implies the requirement to sustain some entity or value over time. Considering what it is that should be sustained, our focus here is primarily on environmental sustainability, calling for "the sustaining into the future of some aspect of the natural environment".[19] Protection of the natural world and environmental security are vital for human life, which depends on the preservation of many benefits provided by the environment. A second key issue inherent in the value of sustainability is a commitment to intergenerational justice and the obligations of each generation to those that follow them. A sustainable approach to biofuels development thus requires that we do not deplete the world's natural resources without regard for the legitimate interests of future generations.

34. The concept of environmental sustainability thus leads to the idea of stewardship. Sustainability requires us to act as stewards of the natural world with legitimate rights to use it, but also with obligations to leave it in a state fit for future generations. We take stewardship to mean that governments and other stakeholders have an obligation to ensure that the natural world and its resources are sufficiently protected, both for current and future generations. Current generations should also ensure that they treat their successors in the same way that they would want to have been treated by preceding generations.

Six Ethical Principles (paragraphs 4.24–4.53)

35. These moral values contain elements that can overlap, and they can in certain circumstances have different implications. We have therefore derived practical Ethical Principles, drawn from one or several of the values, which can be applied more clearly. We thus offer an ethical framework consisting of six Principles which, rather than endorsing a particular course of action

[19] Dobson A (1998) *Justice and the environment: conceptions of environmental sustainability and theories of distributive justice* (Oxford: Oxford University Press), p41.

or technology pathway, can be used to help others to come to decisions about which path to pursue. The first five Principles specify the conditions that should be met for biofuels development to be permissible. These are as follows:

i. Biofuels development should not be at the expense of people's essential rights (including access to sufficient food and water, health rights, work rights and land entitlements).

ii. Biofuels should be environmentally sustainable.

iii. Biofuels should contribute to a net reduction of total greenhouse gas emissions and not exacerbate global climate change.

iv. Biofuels should develop in accordance with trade principles that are fair and recognise the rights of people to just reward (including labour rights and intellectual property rights).

v. Costs and benefits of biofuels should be distributed in an equitable way.

We then consider whether in some cases there may be a duty to develop biofuels. To address this we propose a sixth Principle:

vi. If the first five Principles are respected and if biofuels can play a crucial role in mitigating dangerous climate change then, depending on additional key considerations, there is a duty to develop such biofuels.

The additional key considerations are: absolute cost; the availability of alternative energy technologies; alternative uses for biofuels feedstocks; the existing degree of uncertainty in their development; their irreversibility; the degree of participation in decision making; and the overarching notion of proportionate governance.

36. Our Ethical Principles should guide all policy making in the field of biofuels. We see them as important benchmarks or criteria that policy makers should use whenever technology developments and new policy are envisaged. This alone would represent an important step forward towards more ethical production of biofuels. Our first most, and most general, recommendation is therefore:

37. **We recommend that policy makers and other stakeholders use the Ethical Principles as a benchmark when evaluating biofuels technology and policy development and always make sure that serious consideration has been given to relevant aspects before proceeding.**

38. Finally, as well as considering biofuels against alternative uses for land, such as food agriculture, the Ethical Principles should be considered with regard to the full range of alternative energy technologies, not just fossil fuels. While it is not the aim of this report to undertake such an extensive assessment of all energy technologies, we believe that the ethical framework laid out in this chapter can be applied to all other technologies, and we urge policy makers to do so.

Chapter 5: Ethical Principles and biofuels policy

39. A major cause of the ethical issues associated with biofuels production is not the technologies, but rather the policies that led to their extremely rapid adoption. In Chapter 5, we consider how the interaction of policy, technology and their practical implementation can be filtered through the Ethical Principles, supporting the development of a more ethical 'biofuels system'.

Ethical Principles and their application through policy (paragraphs 5.8–5.10)

40. While we believe that the Ethical Principles developed in Chapter 4 should be adhered to in all biofuels policy, whether existing or newly developed, we are aware of the enormous challenges when developing policy in an area of rapid development and great uncertainty. There can be many difficulties in enforcing a firm ethical framework in the real world, because the policy-making reality is complex, messy and often far from perfect. Moreover, there is also the danger of too much 'red tape' and bureaucratic burden, and the challenge is to develop policy that is proportionate to the specific risks and benefits involved. However, it is precisely because of the extent to which biofuels developments are driven by policy and regulation that it is important to identify where existing policy is failing to meet the required ethical standards, and how this could be avoided or ameliorated.

41. In Chapter 5, we test existing biofuels policies against our Ethical Principles and develop recommendations as to how these policies could be improved. In doing so we are not claiming that this is the only way to proceed; in a complex policy area, there may be other options. However, we believe that our recommendations offer a way forward, and we hope that these will provide helpful guidance for those developing future biofuels policy.

Principle 1: Biofuels development should not be at the expense of people's essential rights (including access to sufficient food and water, health rights, work rights and land entitlements) (paragraphs 5.11–5.23)

42. Target-based policies, such as those contained in the RED, have been criticised for contributing to human rights violations. Firstly, they effectively establish artificial markets for large-scale biofuels production. Biofuels providers, incentivised to fulfil targets, scale up production quickly and in the easiest way possible, often resulting in producers moving into countries with a less rigorous regulatory environment. Secondly, biofuels markets which are supported and incentivised by target-based policies make it attractive for developing countries to scale up their own biofuels production rapidly; however, in some cases this has been associated with human rights violations.

43. The RED has recently incorporated some social requirements, giving a broad commitment to monitoring every two years the impacts of biofuels production on issues related to human rights. In the UK, the Renewable Fuels Agency developed some standards for social sustainability. Within the EU, such standards will not be too difficult to implement and enforce as they are set within a strong legal and policy framework, which supports similar standards in many other areas. However, the RED also proposes equivalent compliance for biofuels sourced *outside* the EU, and enforcement in this context is more difficult to secure.

44. However, a promising international approach is emerging through sustainability initiatives that cover human rights as well as other elements. The Roundtable on Sustainable Biofuels (RSB) standard[20] currently appears to have the most comprehensive set of sustainability criteria relating to human rights. The RSB ultimately aims to operate as a certification scheme.

45. **We recommend to European Commission (EC) and national policy makers that any mandatory national biofuels targets required by the Renewable Energy Directive should be set in such a way as to avoid incentivising human rights abuses. Where monitoring through biannual reports detects such effects, sanctions need to be enacted effectively and swiftly. We recommend that the EC develops and implements effective structures of oversight to this effect.**

[20] Roundtable on Sustainable Biofuels (2010) *RSB principles & criteria for sustainable biofuel production*, available at: http://rsb.epfl.ch/files/content/sites/rsb2/files/Biofuels/Versionper cent202/PCsper cent20V2/10-11-12per cent20RSBper cent20PCsper cent20Versionper cent202.pdf.

46. **We recommend making certification based on comprehensive standards related to human rights mandatory for all biofuels developed in the EU or imported into the EU, for example as part of a certification scheme such as the one developed by the Roundtable on Sustainable Biofuels. This should be included in the Renewable Energy Directive and national policy instruments such as the UK Renewable Transport Fuel Obligation Order.**

Principle 2: Biofuels should be environmentally sustainable (paragraphs 5.24–5.35)

47. Biofuels targets could also harm environmental sustainability because they encourage rapid expansion of current biofuels production and use. At present, such expansion is unlikely to be environmentally sustainable owing to dLUC and iLUC, the relatively poor environmental performance of some current biofuels feedstocks, and the import of biofuels, sometimes from countries with less stringent sustainability regulations. For example, only 31 per cent of biofuels used in the UK met an environmental standard in 2009–2010.[21]

48. The RED includes standards for the protection of areas of high biodiversity which apply to biofuels used towards the EU renewable energy target. Again, the situation is different *outside* the EU. The RED suggests multilateral and bilateral agreements, and voluntary international or national schemes to cover environmental sustainability of biofuels systems outside the EU. Such provisions might lack sufficient 'bite'. Overall, existing policies to ensure sustainability and sound stewardship of biofuels production are weak. This has prompted a number of governments, international organisations and the private sector to develop sustainability standards for biofuels that could be used to support environmental policies and, again, a positive example of this is the RSB. Environmental sustainability of biofuels systems is a global problem. Policies are disparate across countries and the large number of standards and certification systems under development is likely to cause confusion for end users.

49. **We conclude that the best possible standard of environmental sustainability should be developed for biofuels production, for example by an international organisation already working towards such a standard, such as the United Nations Environment Programme. This standard should be implemented as part of a proportionate biofuels certification scheme. This should be achieved in such a way as to prevent displacement and/or the leakage of unsustainable practices into other forms of agriculture.**

50. Technologies for genetic improvement, such as genomics and marker-assisted breeding strategies and genetic modification, could be important tools in achieving a sustainable increase in biofuels production, without endangering the environment, for example by increasing the efficiency of biofuels production at all points in the production pathway. These benefits should be captured, while minimising the risks through appropriate case-by-case risk assessment and post-release monitoring. This applies equally to the introduction of new non-native plants, such as foreign crops, through to the application of nascent technologies such as synthetic biology.

51. **Policies are needed to investigate the application of biotechnologies for genetic improvement of crops where this has the potential to support the environmental performance of biofuels production, with appropriate regulatory oversight.**

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[21] Renewable Fuels Agency (2010) *Year two of the RTFO*, available at: http://www.renewablefuelsagency.gov.uk/sites/rfa/files/Year_Two_RTFO_v2.pdf, p16.

Principle 3: Biofuels should contribute to a net reduction of total greenhouse gas emissions and not exacerbate global climate change (paragraphs 5.36–5.53)

52. Targets may also incentivise the scaling up of biofuels production in countries that do not have climate change mitigation policies, leading to production of biofuels with low GHG emissions savings. In the EU, both climate change mitigation and GHG emissions reductions have become a primary driver for biofuels developments and, accordingly, the RED specifies requirements for net GHG emissions savings from biofuels counted towards the European target. However, without a policy instrument such as a certification scheme ensuring *all* biofuels imported into Europe deliver GHG emissions savings throughout their whole production process ("from field to tank"), the RED could be seen to be 'outsourcing' the pressing problem of climate change mitigation.

53. The recommendation that GHG emissions be measured as part of a life cycle assessment (LCA) raises manifold difficulties itself, including choosing the appropriate type of LCA. Chief among these many difficulties is the debate over iLUC and the extent to which the release of stored carbon can be attributed to biofuels production: these issues have proved to be the most contentious. It is now generally appreciated that biofuels production is one of many activities that can generate dLUC and iLUC, and that dLUC for biofuels production should usually be avoided, and most biofuels policy now requires this. However, such regulations, which only apply to one form of land use, are an ineffective way of dealing with the destruction of carbon stocks. Instead, a much better approach is for internationally agreed policies, with strong monitoring and policing measures, to prevent the loss of major carbon stocks. This would address land use change directly at the point where it takes place and by those who are immediately responsible. If such a targeted approach were successful, the need to consider iLUC would become irrelevant for biofuels or any other activity involving significant land use. We therefore suggest more holistic changes to policy than have recently been put forward by the EC.[22]

54. **We recommend to the European Commission (EC) Directorate-General for Energy and Transport and the UK Department for Transport, Department of Energy and Climate Change, Department for Environment, Food and Rural Affairs and Department for International Development that different biofuel types be certified on the basis of their life cycle greenhouse gas emissions according to attributional life cycle assessment (LCA), and based on a single international standard. This requires elucidation of the important distinction between attributional and consequential LCA. Such certification should be complemented by a robust regulatory mechanism to ensure compliance. The standard should be drawn up by the original authors of the Renewable Energy Directive, including the Joint Research Centre and the subsequent regulators who must translate EC policy into individual Member State practice. The standard should be extended globally, for example in cooperation with the United Nations Framework Convention on Climate Change.**

55. **We recommend to the European Commission Directorate-General for Energy and Transport and the UK Department of Energy and Climate Change, as well as to the United Nations Framework Convention on Climate Change Secretariat, that policies on land use change should be set within a wider framework of global agreement on a coordinated response to climate change, which directly tackles land use change, with strong international and local measures to prevent destruction of high carbon stocks, thereby eliminating or minimising harmful direct or indirect land use change.**

56. Some new biofuels technologies are likely to fare well in terms of their GHG emissions savings, and some may be able to avoid any significant land use change. However, suppliers are obliged

[22] European Commission (2010) *Report from the Commission on indirect land-use change related to biofuels and bioliquids*, available at: http://ec.europa.eu/energy/renewables/biofuels/doc/land-use-change/com_2010_811_report_en.pdf.

to reach target contributions and are penalised financially if they do not. There is thus pressure to avoid penalties, and this may lead developers to choose established technologies over better ones that need further development and investment.

57. **Specific biofuels policies should include technology-relevant instruments to stimulate the development of those biofuels and biofuels crops that can be demonstrated to produce significant net greenhouse gas emissions savings, for example through high biomass yield with minimal inputs and land use. Such instruments could, for example, be developed by national research councils.**

Principle 4: Biofuels should develop in accordance with trade principles that are fair and recognise the rights of people to just reward (including labour rights and intellectual property rights)

Fair trade (paragraphs 5.54–5.66)

58. Much investment in biofuels feedstock production in developing countries has been accused of benefiting neither smallholders nor farm labourers, for example through the use of unfair wages and prices. Moreover, some countries are investing in large-scale biofuels plantations. Given the four to five year maturation of some of these crops (e.g. jatropha), such countries might become vulnerable to changing demand, for example following EU policy changes. On the other hand, the potentially very large expansion of the global biofuels industry stimulated by target-based policies might provide additional revenue and economic development as well as new jobs in developing countries.

59. The protection of labour rights to ensure adequate payment to labourers in all countries producing biomass feedstocks for EU biofuels supplies is addressed in the RED. Again, a key issue is whether countries outside the EU adhere to these protective policies when faced with strong incentives for scaling up biofuels production. One approach to ensure fair wages and fairer trade relationships has been the introduction of Fairtrade schemes;[23] however, these have been criticised for a number of reasons, and some have been connected with fraudulent activity in the past. Instead of simply applying a Fairtrade scheme, trade principles that are fair should be incorporated into the efforts described above, for example as part of certification. These principles should respond to the particularities of biofuels value chains, and also be harmonious with both the complexities of competing drivers and systems of governance that currently drive investment in biofuels.

60. **Current and future biofuels blending targets for the EU and UK need to take a long-term view and promote trade principles that are fair. The effects on developing countries of future changes in targets need to be monitored carefully.**

61. **Given the limitations of current Fairtrade schemes, we propose that trade principles that are fair be developed as part of sustainable biofuels certification requirements by EU and national stakeholders, such as the authors of the Renewable Energy Directive and the UK Department for International Development. This needs to happen in a proportionate and flexible way to acknowledge the differences between countries and production systems, while at the same time strictly maintaining the protection of vulnerable populations.**

Intellectual property (paragraphs 5.67–5.84)

62. Just reward also means finding a balance between rewarding parties for their innovation and investment while trying to encourage access to knowledge and materials. For biofuels in many

[23] Fairtrade International (2011) *What is Fairtrade?*, available at: http://www.fairtrade.net/what_is_fairtrade.0.html.

cases, financial return will only be possible after the investment of very large sums of money, and intellectual property (IP) will play a key role in attempts to secure such a return. Intellectual property regimes are fraught with tensions and political agendas, and there has been a tendency towards more and stronger intellectual property rights (IPRs) over the years. In the negotiations around trade agreements that address IPRs, developing countries often have very little influence.

63. It is unrealistic and probably economically imprudent to suggest that the number or scope of IPRs should be reduced. An alternative approach might be to recognise the distinction between their existence and their exercise. Another approach is to influence the way in which IP is exploited – which is done principally through the granting of licences. The widespread use of non-exclusive licences which utilise the principles and best practices outlined in a recent OECD report[24] should be encouraged in the area of biofuels.

64. **We recommend the drafting and adoption by the UK Intellectual Property Office of a licensing scheme and a framework of biofuels principles and best practices along the lines of the Organisation for Economic Co-operation and Development guidelines.**

65. **We recommend increasing the availability of licensing arrangements with respect to biofuels technologies and more research on the economic and social impacts of intellectual property in these fields.**

66. Plant breeding strategies may lead to the development of new plant varieties that can be protected by plant variety rights. These provide a reward for innovation but permit access to the results of innovation, for example through the breeders' exemption. This allows breeders to use protected material for the purpose of breeding other varieties without the authorisation of the plant variety right holder. Where this research leads to a new variety, the breeder of the new variety can claim rights over it without having to obtain permission from the first breeder. This reflects public interest in allowing breeders free access to plant material to breed new varieties.

67. **We recommend to the UK Department for Business, Innovation and Skills and the Intellectual Property Office the introduction of the breeders' exemption into UK patent law.**

Principle 5: Equitable distribution of costs and benefits (paragraphs 5.85–5.102)

68. Equitable cost–benefit distribution is the only one of our Principles that is not in some way addressed in specific current biofuels policies or in the continuing initiatives to establish biofuels sustainability standards. The costs and benefits of biofuels production relevant to equity extend well beyond purely financial losses or revenue. They may be complex, ranging from environmental to political, social or economic aspects, and accumulate in different ways in different contexts. There is also a distinction between benefits that might be described as public goods and benefits which may accrue only to certain segments of society in certain parts of the world. The specific benefit of a public good also needs to be offset against the burdens on others in society. For example, investment in biofuels to reduce GHG emissions may pose livelihood implications for only certain, poorer or more vulnerable, segments of society. Trade-offs in creating policy that aims to distribute costs and benefits equitably are inevitable, and it is more realistic to aim to ensure that policy (broadly) maximises benefits and reduces costs, while ensuring that additional inequities are not created in an already inequitable world.

69. A key concern regarding the equitable international distribution of biofuels benefits is to ensure appropriate management of global versus local production. There are many examples of successful, small-scale, local biofuels initiatives that provide energy, income and livelihoods in fuel-poor areas, such as in rural Mali. Policies that encourage biofuels production therefore need

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[24] Organisation for Economic Co-operation and Development (2006) *Guidelines for the licensing of genetic inventions*, available at: http://www.oecd.org/dataoecd/39/38/36198812.pdf.

to balance production for local needs and production for international markets. It is also important to recognise that policies aimed at ensuring sustainable industrial production, such as, for example, certification, have to be wielded with care. Where local small-scale production serves important needs, such as providing essential fuel and energy, certification should allow for exceptions in order not to stifle such production and disadvantage small-scale producers in developing countries.

70. **We recommend that biofuels policy and future sustainability and certification initiatives should not discourage decentralised biofuels production, particularly in developing countries that suffer from fuel poverty.**

71. **Protection against the imposition of unfair costs on vulnerable populations should be developed and implemented.**

72. Public–private partnerships (PPPs) constitute one mechanism for risk and benefit sharing and the development of technologies and products. Where they exist, these partnerships sometimes involve public–private interaction between multiple stakeholders, opening up new innovation pathways in areas where there are barriers to development such as market failures or lack of incentives for commercial development. With appropriate adaptation to local contexts and the policy areas involved in biofuels, such PPPs could be envisaged for biofuels.

73. **Policy instruments, such as innovation incentives, bilateral agreements between the UK and other countries, and project funding, should be developed and implemented to ensure that benefits of biofuels production are shared equitably. This could, for example, be done through public–private or product-development partnerships. National instruments should be implemented with the help of governmental departments such as the UK Department for International Development and Department of Energy and Climate Change. International organisations such as the United Nations Framework Convention on Climate Change could oversee international schemes.**

General policy instruments (paragraphs 5.103–5.123)

74. In addition to these biofuels-specific instruments, a wider policy background is relevant to meeting our Ethical Principles in biofuels systems, such as research guidelines. Research outcomes can be important elements in either causing or mitigating some of the ethical problems discussed. Existing academic ethical guidelines are probably sufficient for early-stage academic research where it is unclear what the basic research outcomes are going to be. However, once basic research outcomes have been clarified, i.e. at the stage of proof of concept, our ethical framework could be used as a checklist or benchmark for considering whether a technology has the potential to violate one of our Ethical Principles.

75. **We recommend to research councils, funders and managers that work should be undertaken to evaluate the likely ethical effects of implementing particular biofuels technologies on a larger scale. This should happen at the stage of proof of concept. In the future, ethical impact assessment should become a requirement of larger research grants aimed at bringing technologies towards wider commercial use.**

76. The IP regime can play a role in ensuring that the costs and benefits associated with biofuels are distributed in an equitable way. This could be achieved by taking one of the key objectives of the Convention on Biological Diversity (CBD)[25] – i.e. the fair and equitable sharing of the benefits arising from the utilisation of genetic resources – and integrating it into the IP regime. In 2010, agreement was reached on a legally binding protocol to the CBD on access to, and sharing of,

[25] Convention on Biological Diversity of 1992.

the benefits from the use of genetic resources, called the Nagoya Protocol. If successful, the Nagoya Protocol would allow developing countries, in particular, to exploit their genetic resources and reduce possible occurrences of misappropriation of those resources. This in turn may alleviate some of the harmful consequences that the Trade Related Aspects of Intellectual Property Rights[26] (TRIPs) Agreement has had on developing countries. The UK should take the lead in ensuring the operation of such an effective global multilateral benefit-sharing mechanism.

77. **We recommend to the UK Department for Business, Innovation and Skills and the Intellectual Property Office that the UK continues to promote compliance to access and benefit-sharing schemes by all users of genetic resources including those employing them for the purposes of biofuels production.**

78. **We also recommend that a 'disclosure of origin' requirement be introduced into UK patent law to improve transparency about genetic resource use in order to facilitate access and benefit sharing.**

79. **We recommend that consideration be given to the introduction of a mandatory 'disclosure of origin of genetic resources' requirement in intellectual property law with appropriate sanctions, either outside or within patent law, for non- or incorrect disclosure.**

80. **We recommend that the UK updates current access and benefit-sharing arrangements to take account of the legislative, administrative and policy measures introduced in the Nagoya Protocol on Access and Benefit Sharing. This process could be overseen by the UK Department for International Development and should be integrated into more specific biofuels polices, such as a sustainability standard and certification scheme.**

81. **We recommend to the UK Department for International Development that the UK should take the lead in giving support to developing countries to set up competent national authorities on access and benefit sharing and in providing advice on the practical implementation of the requirements of the Nagoya Protocol and Bonn Guidelines.**

82. **We recommend that international organisations such as the World Trade Organization and the World Intellectual Property Organization look into the feasibility of integrating the key concepts of the Convention on Biological Diversity into intellectual property law. This may lessen the adverse impact that the Trade Related Aspects of Intellectual Property Rights Agreement has had on developing countries.**

Chapter 6: Biofuels and the bigger picture

83. Biofuels occupy a space where almost all of the great future challenges facing the world converge – the so-called 'perfect storm'. As Sir John Beddington asked, how can we feed 9 billion people? How can we respond to future demand for water? Can we provide enough energy to supply the growing population coming out of poverty? Can we do all this while mitigating and adapting to climate change?[27] And, we would like to add, can we do all of this while protecting basic human rights and maintaining ecosystem services?

84. No single technology can address all these challenges. A mix will be necessary, and we believe that biofuels should be part of that mix if they overcome the hurdles of our Ethical Principles. There is a significant role for biofuels to contribute to some dimensions of energy security, in particular in the transport sector, as well as to climate change mitigation by reducing fossil fuel consumption, especially given the new scientific advances described in Chapter 3. There is significant energy available in biomass that can be accessed within a relatively short timescale. Moreover, there is a medium-term requirement for transitional technologies that can work with

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26 Agreement of Trade Related Aspects of Intellectual Property Rights of 1994, Part II.

27 John Beddington (2010) *Food, energy, water and the climate: a perfect storm of global events?*, available at: http://www.bis.gov.uk/assets/bispartners/goscience/docs/p/perfect-storm-paper.pdf.

current infrastructure to deliver renewable transport fuels during the transition to future more effective solutions. While uncertainty remains about the extent of the potential contribution of biofuels to climate change mitigation, they have an impressive potential range of production scales. There are strong reasons to support biofuels developments that will, given an appropriate and proportionate policy environment, comply with our Ethical Principles, alongside other renewable energy sources and attempts to reduce overall demand for energy.

Some general considerations (paragraphs 6.13–6.26)

85. To support ethical biofuels production, the best use of current biomass resources needs to be found. In addition to our Ethical Principles, practical tools of comparative assessment, such as cost curves using a multitude of criteria and indicators, should be employed as an essential part of informed policy and decision making. In addition, because of their apparent advantages over established biofuels, the potential of the new approaches should be explored further. There is a large discrepancy between the powerful targets and related penalties that are in place for currently used biofuels and the very few incentives for new methods for developing biofuels that would stand a better chance of complying with our Ethical Principles.

86. **We recommend to research councils that specific policies be developed and implemented that directly incentivise research and development of new and emerging biofuels technologies that need less land and other resources, avoid social and environmental harms in production, and deliver significant greenhouse gas emissions savings.**

87. Modern biotechnology, including advanced plant breeding strategies and genetic modification, might play a central role in bringing about further improvements. Therefore, the regulation of these technologies should be considered in the light of new evidence on risks and benefits. Although developed with the best of intentions at a time when there was much more uncertainty around the potential risks and benefits of genetic modification, current regulatory systems might no longer be in accord with recent evidence-based assessment. In order not to be overly restrictive and prevent the development of technologies that have the potential to contribute to meeting the requirements of our Ethical Principles, these policies should be reviewed.

88. **We propose that, in order to address our Ethical Principles effectively, some modifications might be needed to existing policies and regulations related to new crop developments for agriculture and forestry. This might require some modifications to international agreements. Evidence-based and proportionate review of these policies should take place as soon as possible.**

Implementing Principle 6 (paragraphs 6.27–6.38)

89. Having looked at Principles 1–5, how do we determine whether there is a responsibility to develop biofuels? Meeting the standards required by Principles 1–5 is but the first step to establishing that a biofuels technology should become an ethical imperative and can be adopted widely. Such a duty also depends on whether a number of additional key considerations are met. These relate to the efficient, effective and equitable use of resources and technology, and we need to ask the following questions of any technology before it is considered for wide implementation:

- Will the costs of the development be out of all proportion to the benefits, compared to other major (public) spending priorities?
- Are there competing energy sources that might be even better, for example at reducing GHG emissions, while still meeting all the required Ethical Principles?
- Is there is an alternative and better use of the biomass feedstock?

- Is sufficient attention given to the areas of uncertainty in the development and implementation of a technology, and are there efforts to reduce them?
- Will the implementation of the technologies lead to irreversible consequences and damage, once they are scaled up?
- Has fair attention been paid to the voices of those directly affected by the implementation of a technology?
- Can policy instruments such as certification be applied in a proportionate way?

90. Answering these questions in the context of Principle 6 should be part of a comprehensive comparative analysis of all different future energy and climate change abatement options, including comparison of energy *portfolios* with a different mix of technologies. In fact, our ethical framework as well as the questions we draw could serve as a template or a benchmark against which the ethical robustness of a range of possible pathways can be assessed. It could be a yardstick to hold up against a range of options to decide which is most appropriate in the future – a checklist of ethical appropriateness.

91. Put simply, if a technology, or a particular mix, after careful consideration of this checklist meets our Ethical Principles 1–5 and has a positive evaluation under the additional considerations of Principle 6, then there is a duty to develop it.

92. **We suggest that UK and EU policy makers as well as those in the research community conduct comparative analysis of different energy portfolios rather than simply different technology options.**

93. **We encourage UK and EU policy makers undertaking comparative analyses of the impacts of different energy and climate change abatement technology options to apply our Ethical Principles 1–6 as a template or benchmark against which the ethical robustness of a range of possible pathways can be assessed when engaging in policy and technology appraisal.**

94. **If a biofuels technology, or a particular mix, meets all elements of our Ethical Principles 1–6 then there is a duty to develop it.**

An approach to support Ethical Principles 1–6 (paragraphs 6.39–6.50)

95. In trying to bind together the more specific recommendations we have proposed in Chapter 5, we believe a proportionate governance approach, consisting of standards, targets, certification schemes and regulatory systems, will be helpful to guide future governance and policy developments. While *targets* provide long-term stability to developers and other stakeholders, targets of the type used in the RED are very blunt instruments, and we believe that the incentivisation of a particular technology development should be more sophisticated and responsive.

96. **We recommend that policy makers at the European Commission level and in Member States replace current Renewable Energy Directive and national biofuels targets with an alternative, proportionate, target-based strategy that is in accord with our Ethical Principles and that drives change in a more nuanced, flexible and responsive way.**

97. Biofuels-specific *standards* and *certification schemes*, continually improved, will be important instruments of change in biofuels developments. They will be most effective if they are accompanied by elements from *regulatory systems*, for example financial sanctions, and incentives such as subsidies or assured markets where specific standards are met. However, so far, despite the best intentions, the outcomes of such initiatives have not been entirely positive. Our policy recommendations refer to the need to use these instruments intelligently to effect improvements in the biofuels systems, and this requires continuing monitoring of impacts.

98. **We suggest the development and implementation of a comprehensive ethical standard for biofuels, to include the protection of human rights and the environment, full life cycle assessment of greenhouse gas emissions, trade principles that are fair, and access and benefit-sharing schemes. It should be set within wider frameworks for mitigating climate change and addressing land use change (direct and indirect), and should be open to future revision as needed.**

99. Standards need to be enforced, and the instrument of choice to ensure this is *certification*. The latter instrument needs to be wielded with care and include some clear guidance to enable their proportionate application. Certification, as it is envisaged here, implements our Ethical Principles which should ideally apply across all EU Members States, if not globally, with accompanying efforts in monitoring its impacts.

100. **The ethical standard for biofuels should be enforced through corresponding certification for all biofuels developed in and imported into the EU. We recommend that, instead of voluntary schemes developed by each Member State, a unified certification scheme be developed and implemented. Such certification should allow for proportionate application, for example in the case of local small-scale biofuels production. The EU should provide financial support and advice to countries who might find it difficult to implement such certification.**

Why just biofuels? (paragraphs 6.51–6.59)

101. We have suggested above that a comprehensive standard should be applied to biofuels production through certification. However, several elements of the standard and the associated certification scheme should ideally be applied equitably to *all* similar products and not just biofuels. There is no reason why our ethical framework and its Principles should apply to just one sector of agricultural and technological activity. In particular, the considerations flowing from Principle 6 apply to many technologies and activities, not just to biofuels. Indeed, there is a risk that in putting barriers (i.e. ethical conditions) in the way of biofuels development, this could inhibit their development, while the Principles we have developed continue to be violated in other agricultural, energy generation or trade practices. We therefore propose that our Ethical Principles be used as a model or benchmark in *all* comparable technologies and products, taking one important step towards the development and improvement of the wider policy context that is needed to tackle the enormous challenges of the future.

102. **We recommend that our Ethical Principles be applied, ultimately, as a benchmark to all comparable technologies and products.**

Introduction

1. This report focuses on the technologies, policies and drivers that promote the development of liquid biofuels for transport. This is an area where science and technology seem to be promising innovative approaches that could improve the capacity of biofuels to contribute to climate change mitigation while at the same time resolving some of the ethical challenges that have been evident in the production of current biofuels.

2. Some take the position that "biofuels are bad" because they believe they compete with food production and (to some extent) allow our transport-driven lifestyles to continue. Our view has been that the scale of the challenges we face, from climate change to food security and energy security, requires us to consider all possible approaches to their resolution, one of these being the use of biofuels for transport.

3. The topic of biofuels is complex and multifaceted and in crafting the remit for this report the Nuffield Council had to take account of what is manageable within a given timescale. We have focused on liquid biofuels for transport because this seemed to be an area that is containable within a conceptual boundary, bringing together technologies, policies and drivers that will be amenable to an ethical analysis. Having said that, there are important links to other pressing questions, such as whether it is more appropriate to use biomass for energy generation in general rather than for liquid biofuels.

4. We thus recognise the many areas that are not covered by this report, and of the many alternative approaches we could have taken in relation to biofuels development. To quote an author who is no stranger to controversy, "Every story one chooses to tell is a kind of censorship – it prevents the telling of other tales".[28] This quote resonates with our choice of subject and its coverage in this report – although we relocate the question of biofuels use in a wider environment in the final chapter. The quote is equally relevant to one of the most important issues related to biofuels development, that of 'lock-in' – given the large-scale infrastructures that are an integral part of modern fuel delivery systems, it becomes very difficult to implement new kinds of product or new approaches to biofuels development that are not compatible with the current fossil fuel related infrastructure.

Background

5. The world's lifestyle is fuel dependent and fuel hungry, and it is expected to be even more so in the future. Total world consumption of petroleum products in 2009 was 13.3 billion litres per day. Of this, consumption of motor petrol[29] was approximately 3.4 billion litres per day in 2006 and 826 million litres per day were consumption of jet fuel.[30] Total marketed world energy consumption has been predicted to increase by 49 per cent between 2007 and 2035. This significant increase is mainly attributed to increased demand in developing countries that are not members of the Organisation for Economic Co-operation and Development (OECD). In these countries, energy consumption is forecast to increase by 84 per cent, compared with an increase of a comparatively modest 14 per cent in OECD countries.[31] Fuel for transport – cars, aviation and shipping – makes up almost one-third of

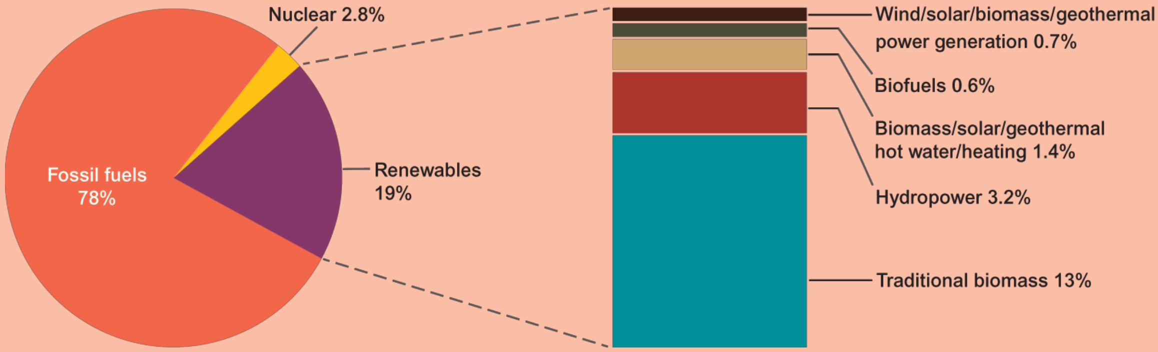
[28] Salman Rushdie (1995) *Shame* (London: Vintage).
[29] US Energy Information Administration (2009) *International energy statistics*, available at: http://tonto.eia.doe.gov/cfapps/ipdbproject/iedindex3.cfm?tid=5&pid=62&aid=2&cid=ww,&syid=2005&eyid=2008&unit=TBPD.
[30] Ibid.
[31] US Energy Information Administration (2010) *International energy outlook 2010 – highlights*, available at: http://www.eia.doe.gov/oiaf/ieo/highlights.html.

total world delivered energy consumption,[32] and this demand will rise over the next 25 years.

6. Over the last few decades, biofuels have emerged as a possible yet controversial alternative to fossil fuels, in particular in the transport sector. Biofuels are renewable liquid or gaseous transport fuels derived from plant or animal material (biomass).[33] Our ability to develop biofuels is not new but there has been a very significant increase in the production and use of biofuels since around 2000. This has been stimulated by concerns about: the fluctuating, but generally increasing, price of fossil fuels; worries about energy security; prospects for improved economic development; and the perceived potential of biofuels to mitigate climate change through reduced greenhouse gas (GHG) emissions.

7. At the moment, biofuels production and consumption make up only a small proportion of world energy use (see Box 1); however, this amount is steadily increasing. Between 2005 and 2007, world biofuel production rose from approximately 2.5 billion litres per day to more than 5.6 billion litres per day.[34] This amounts to more than a 100 per cent increase in production; a trend expected to continue. For example, a recent study from the Institute for European Environmental Policy estimated that 8.8 per cent of transport fuel in Europe would be biofuels by 2020.[35]

Box 1: Biofuel energy share of global final energy consumption, 2008[36]



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8. The main types of biofuels currently in commercial use in the UK are bioethanol and biodiesel made from conventional harvested products of food crops (e.g. grain).[37]

[32] US Energy Information Administration (2010) *International energy outlook 2010*, available at: http://www.eia.doe.gov/oiaf/ieo/world.html.
[33] Parliamentary Office of Science and Technology (2007) *Transport biofuels*, available at: http://www.parliament.uk/documents/post/postpn293.pdf.
[34] US Energy Information Administration (2009) *International energy statistics*, available at: http://tonto.eia.doe.gov/cfapps/ipdbproject/iedindex3.cfm?tid=79&pid=79&aid=1&cid=ww,&syid=2005&eyid=2008&unit=TBPD.
[35] Institute for European Environmental Policy (2010): *Anticipated indirect land use change associated with expanded use of biofuels and bioliquids in the EU – an analysis of the National Renewable Energy Action Plans*, available at: http://www.ieeplondon.org.uk/publications/pdfs/2010/iluc_analysis.pdf, p2.
[36] Renewable Energy Policy Network for the 21st Century (2010) *Renewables 2010: global status report*, available at: http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR_2010_full_revised%20Sept2010.pdf, p15. 'Traditional biomass' refers to unprocessed biomass that is burned in stoves or furnaces to provide energy for cooking, heating and agricultural and industrial processing, typically in rural areas. Examples include collected fuel wood, agricultural waste and animal dung. These types of biomass have been in use in poor regions of the world for a long time. Our report does not focus on these types of biofuels, but rather on those which are specifically developed as liquid fuels to replace fossil fuels in transport.
[37] From April 2009 to April 2010, biodiesel accounted for 71 per cent and bioethanol for 29 per cent of biofuels supplied in the UK; see: Renewable Fuels Agency (2010) *Year two of the RTFO*, available at: http://www.renewablefuelsagency.gov.uk/sites/rfa/files/Year_Two_RTFO_v2.pdf, p16.

Bioethanol is a type of alcohol produced by fermentation of sugars or starches from sugar cane, sugar beet, wheat or corn. Biodiesel is mainly made from vegetable oils from oilseed rape, soybean, sunflower and oil palm, in a chemical reaction called 'transesterification'. These biofuels can be blended with fossil fuels, such as petrol and diesel (currently up to 10 per cent biofuel), or used alone, to power vehicles.

9. Another biofuel in current use is biogas, a methane-rich gas which is produced from decomposition of animal or plant material (a process called anaerobic digestion), and either collected from landfill sites or sewage treatment works, or produced in dedicated biogas production facilities. Once purified, it can be burned at the source of its production to generate heat and/or power or distributed by existing natural gas pipeline systems. Biogas can also be compressed to provide fuel (i.e. compressed or liquefied biogas) for modified road vehicles.

10. As well as for transport fuel, biomass and biofuels can be used for other purposes such as heat production, electricity generation (in co-fired power plants or dedicated biomass power plants) and combined heat and power generation. The use of biomass for heat and power generation is relatively well established,[38] whereas the use of biofuels for heat and power is still limited.[39]

11. The biofuels that have seen significant increases in production in recent years – those developed from crops such as corn, soybean and oil palm – are frequently referred to as 'first generation biofuels'. Future more advanced biofuels developments are commonly described as 'second', 'third' or even 'fourth generation biofuels', depending on the type of biomass used and how it is converted to biofuel. The various labels reflect the diversity of continuing biofuels developments, with a mix of technologies and production pathways being pursued simultaneously. In this report, we distinguish between two phases of biofuels development: biofuels established on a commercial scale today (established or current biofuels); and new biofuels under development (new or future biofuels).

The structure of the report

12. In recent years, the expanded production of biofuels has attracted considerable controversy. While many of the controversial issues are not unique to biofuels, biofuels are the focus of this report because of the current attempts at their promotion and regulation. Hence, this report examines the ethical aspects of biofuels and proposes an ethical framework for judging their future suitability among various technology and policy alternatives. This framework has the potential for wider application to the necessary evaluation of such alternatives and beyond. In order to consider the ethical implications of biofuels, this report looks at the impacts of established biofuels. It also examines in what way new biofuels could resolve or avoid any of the ethical dilemmas associated with established biofuels. In Chapter 1, we outline the drivers for the rise of biofuels production and use, and describe why biofuels were seen as an attractive option in the pursuit of improving the sustainability of energy supply.

13. In continuing this story, Chapter 2 presents, for illustrative purposes, three case studies of established biofuels, detailing the debates surrounding the unforeseen problems that emerged when these biofuels were produced on a large scale. Quite quickly it became apparent that there were serious ethical and social implications associated with large-scale

[38] Department for Environment, Food and Rural Affairs (2007) *UK biomass strategy*, available at: http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/explained/bioenergy/policy_strat/1_20091021164854_e_@@_ukbiomassstrategy.pdf, Section 5.

[39] In 2009, "small quantities" of biofuels produced in the UK went to the UK heat and power market; see: AEA Technology (2010) *UK production of biofuels for transport in 2009: executive summary – Report to DECC*, available at: https://restats.decc.gov.uk/cms/assets/Uploads/Results_2009/RestatsUKBiofuelsProduction2009Abstract27July10.pdf, piv.

production, including concerns that biofuels production has negative effects on world food availability and prices – the 'food versus fuel' debate – and that it endangers the environment as well as workers' and farmers' rights.

14. Chapter 3 offers a brief overview of some of the new and emerging biofuels technologies. Currently under development, these are being designed with the aim of circumventing, or at least alleviating, some of the problems related to established biofuels production. We focus on two examples: lignocellulosic biofuels and fuel from algae.

15. Chapter 4 then lays out the ethical framework by introducing a series of Ethical Principles. This framework can be used to appraise the impact of established biofuels and evaluate the potential of new biofuels, which might avoid the issues of the established generation of biofuels. It also provides a basis for decision making as to whether and under what circumstances biofuels should be encouraged as a source of fuel in the UK and other parts of the world.

16. We apply the ethical framework in Chapters 5 and 6. In Chapter 5, we discuss the legal, policy and governance context of biofuels and policy challenges for the future, and we develop some recommendations for policy makers based on this discussion. Chapter 6 broadens the discussion towards alternative technologies and develops some overarching conclusions. We close by setting out the conditions under which there could be a duty to develop biofuels.

17. Throughout the report, we provide quotes from responses to our public consultation. In these instances, we have been given permission by the respondent to do so. In some cases, permission was granted for an anonymous citation only. While we have tried to select statements that represent broad areas of consensus, or unique, significant points, they should be taken to be illustrative of a debate rather than representative. More information on the consultation results is available in Appendix 2 (Wider consultation for the report) and all responses for which permission was given to be published are available on the Council's website.

Our starting point

18. In this report we take it as a given that there is a strong ethical imperative to improve energy efficiency and to reduce fuel consumption from unsustainable sources. While there is some debate as to which approaches are best suited to achieve these goals, the general point is widely accepted. We recognise that such efforts need to be pursued with the highest priority, and that contained within the aim of reducing fossil fuel consumption, there is a need to look into alternative fuel sources, especially given the demand for transport fuel that is predicted to rise.

19. Investigating the ethics of biofuels, and, in particular, some of the new approaches, is the remit that the Working Party was charged with for this report. Biofuels are, of course, just one amongst several alternatives being pursued to produce energy for the future. Others include: biomass for heat and power; wind and solar energy; and nuclear power. New energy sources such as hydrogen are also being explored, and many foresee extending the use of electricity in the transport sector. Fossil fuels are likely to remain prominent, however, particularly if emissions from the use of coal and gas in power stations and industry can be dramatically reduced with carbon capture and storage technologies. While this report focuses on new approaches to liquid fuels for transport, its arguments, conclusions and recommendations need to be set against the context of other existing or potential energy sources. Indeed, we envisage that the ethical framework developed in Chapter 4 should also be used in the comparative evaluation of other types of energy and fuel sources. Eventually, such an approach must be extended to all areas of human activity that raise similar or related ethical issues. We take up this issue briefly in Chapter 6.

20. New approaches to biofuels are evaluated in this report as potential candidates for inclusion in the future energy portfolio. This will be more heterogeneous than past portfolios, varying between different regions and countries and including a mix of energy options. One concern is, therefore, to avoid either premature foreclosure or premature endorsement of particular new approaches without first conducting an analysis of scientific, economic, social, legal and ethical aspects, as well as of policy and governance issues. By contributing to such a discussion, the report aims to provide the general public and stakeholders with helpful information on biofuels, which can inform their decisions as consumers, investors, policy makers and scientists.

21. Owing to our expertise and location, several of our recommendations address UK and European policy makers. However, biofuels give rise to and are part of a number of international – indeed, global – issues, and, wherever we address these, our recommendations are aimed at (global) industry, international organisations and those engaging in policy making on the world stage.

Chapter 1

Why biofuels? Drivers for biofuels production

Chapter 1 – Why biofuels? Drivers for biofuels production

Box 1.1: Overview

Biofuels have attracted increasing interest over the last few decades. As fuels made from locally grown renewable sources, they have been proposed as an alternative to expensive fossil fuels. Moreover, they appeared to provide a single solution to three of the most important challenges of modern life, which include:

- worries over energy security;
- an interest in economic development, both in the developed world and developing countries, including the creation or sustaining of jobs in agriculture; and
- the need to mitigate climate change and achieve lower greenhouse gas (GHG) emissions.

These challenges and the attempts of policy makers and other stakeholders to address them have contributed to a rapid adoption of biofuels technology.

In Chapter 1, we take a closer look at these drivers and discuss their contribution to the current situation in biofuels development, use and policy making.

History of biofuels

1.1 Biofuels are not new. When first demonstrating the engine bearing his name, Rudolf Diesel ran it on peanut oil at the World's Fair in Paris in 1900.[40] Interest in both vegetable oils as fuels for the internal combustion engine and plant material for ethanol production for transport fuel was also reported in several countries during the 1920s and 1930s and later during World War II where there were serious fuel shortages, for example in the UK and Germany. In an interview in 1925, Henry Ford, founder of Ford Motor Company, envisaged the processing of fruit and other plant material into fuel for cars: "The fuel of the future is going to come from fruit like that sumac out by the road, or from apples, weeds, sawdust – almost anything. There is fuel in every bit of vegetable matter that can be fermented. There's enough alcohol in one year's yield of an acre of potatoes to drive the machinery necessary to cultivate the fields for a hundred years."[41]

1.2 In the 1950s and 1960s, the first patents for industrial production of biofuels began to appear but petroleum-based fuels remained dominant throughout the 20th century, mainly owing to low crude oil prices. However, during the 1940s, Belgium, France, Italy, the UK and Germany each investigated the use of vegetable oil fuels and, during World War II, Brazil, Argentina, Japan and China used vegetable oils as fuel.[42]

1.3 Interest in biofuels was reinforced in the later decades of the 20th century by various legislative and political acts.[43] The oil embargo by the Organization of the Petroleum Exporting Countries OPEC in 1973–1974, which led to a sharp increase in crude oil prices, also led to worldwide interest in alternative energy sources, including biofuels. This was also

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40 Knothe G (2001) Historical perspectives on vegetable oil-based diesel fuels *Inform* **12**: 1103–7.

41 The New York Times (19 Sep 1925) *Ford predicts fuel from vegetation; he says electricity will heat cities in the future, tells of testing a new flour*, available at: http://query.nytimes.com/mem/archive/pdf?res=F30A15FA3E5B13718DDDA90A94D1405B858EF1D3.

42 Knothe G (2001) Historical perspectives on vegetable oil-based diesel fuels *Inform* **12**: 1103–7.

43 For example, the year 1970 saw the passage of the US Clean Air Act by the US Environmental Protection Agency (EPA). This Act allowed the EPA to regulate more closely emissions standards for pollutants such as sulphur dioxides, carbon monoxide, ozone, nitrogen oxides, and particulates and thus provided an incentive for US research to develop cleaner burning fuels.

the first time that worries over dependence on oil-based fuel imports were discussed publicly in many countries in the Western world.

Modern drivers of biofuels development

1.4 In recent years, several major challenges to the modern world and its way of life have become a focus of public interest. By the end of the 20th century, governments and policy makers around the world faced three key issues:

- (renewed) worries about energy security;
- an interest in economic development, both in the developed world and developing countries, including the creation or sustaining of jobs in agriculture; and
- the need to mitigate climate change and achieve lower greenhouse gas (GHG) emissions.

1.5 Fuels made from locally grown renewable sources were proposed as a contribution to addressing all three of these challenges, as well as providing a potentially cheap alternative to expensive fossil fuels. Moreover, they were also seen as a way of addressing some additional, important concerns at the time, including those over lead in fuel and losses of agricultural jobs and farming subsidies. There was also an interest in biofuels as a source of octane. From the point of view of many involved, biofuels looked like an extremely attractive option, and thus the decade 1995–2005 saw several new supportive policies for biofuels in the European Union (EU) – including the UK – and the US, as well as in many other countries around the world. These policies established markets for biofuels and acted as incentives to industry to invest in biofuels development and production. As a consequence, biofuels became available on a small but significant commercial scale, and this has remained the case.

1.6 The above three drivers, which are to some degree interlinked, have become increasingly important and the motivation to develop alternatives to fossil fuels remains strong. The following sections take a closer look at these drivers and discuss their contribution to the current situation in biofuels development, use and policy making.

Energy security

"Internal combustion engines will be used for a long time to come around the world. There are few alternatives to crude oil when it comes to transport, which is quite different to the broader energy picture (including heat and electricity). There is therefore a strong case for channelling a significant volume of biomass into liquid biofuels for transport."[44]

"Biofuels offer the potential to diversify at least some of the reliance on import of fossil fuels, and to produce home-produced fuels."[45]

What is energy security?

1.7 Much of the world's extraordinary economic progress over the last century has been facilitated by reliable and affordable sources of energy. However, at the beginning of the new millennium, one of our biggest challenges is continuing to meet rising energy demand in a sustainable way, and energy security has become a constant and universal issue.

1.8 In its 2000 Green Paper, the European Commission (EC) took energy security to be: "the uninterrupted physical availability of energy products on the market, at a price which is

[44] Swan Institute, Newcastle University, responding to the Working Party's consultation.
[45] NNFCC, responding to the Working Party's consultation.

affordable for all consumers (private and industrial)".[46] Threats to energy security come in many forms. Some can disrupt the provision of energy to consumers and businesses (e.g. through limited availability of fuel), while others affect the price of energy (e.g. price spikes as a result of geopolitical tensions and war). Threats can be immediate or longer term, and can originate from inside or outside the country affected. Furthermore, the impacts of energy insecurity can be uneven. For example, energy-intensive businesses and fuel-poor households[47] are particularly vulnerable to the effects of high energy prices. Moreover, as economies transition to low carbon patterns of energy production and use to tackle climate change, the challenge of energy security becomes one in which the threats to availability and affordability will change over time.

1.9 Energy security discussions often make a distinction between strategic security and operational security. For example, in considering 'security of supply', the UK Committee on Climate Change (CCC) distinguishes between technical security of energy supply ("the degree of certainty that energy supply will be available immediately and on demand when customers want it") and geopolitical and economic security of energy supply ("the extent to which the UK can be free of reliance on sources of energy which are geopolitically insecure or inherently and harmfully volatile in price").[48] It is often assumed that energy imports are inherently less secure than domestic 'home-grown' sources of energy, and this is commonly used to argue for increasing biofuels production from local sources. In reality, however, energy security depends on factors that are both domestic (e.g. infrastructure) and international (e.g. volume of fuel produced, prices). Access to international sources of energy can, for example, often lead to lower energy prices.

1.10 The importance of energy security is seldom disputed, but the dimensions of security that are most important – and the types of energy production and use that are required to address risks to energy security – are hotly debated. Proponents of non-fossil energy sources such as wind power, nuclear power and indeed biofuels often argue that these sources will improve security. However, the extent to which these sources can maintain or improve levels of security depends heavily on context. For example, it depends on what energy sources they are replacing, how they are deployed, and what other sources are deployed alongside them. Biofuels have a relative advantage over, for example, wind energy because they can be stored. In addition, the security benefits of energy efficiency are more universally acknowledged and lower energy demand and consumption is therefore a primary goal to secure energy security in the long term.

Threats to energy security

1.11 There are many potential risks to energy security, and these can be divided into four main categories:[49]

- risks due to fossil fuel scarcity or disruptions to fossil fuel supplies from international markets;
- risks due to a lack of investment in domestic national energy infrastructure;
- risks from technology and infrastructure failures; and
- risks due to industrial activism or terrorism.

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[46] European Commission (2000) *Green Paper: towards a European strategy for the security of energy supply*, available at: http://ec.europa.eu/energy/green-paper-energy-supply/doc/green_paper_energy_supply_en.pdf, p3.

[47] I.e. when a household is unable to afford adequate warmth because it lives in an energy-inefficient home where it is necessary to spend more than 10 per cent of the family income on energy services; see: Boardman B (1991) *Fuel poverty: from cold homes to affordable warmth* (London: Belhaven Press), p205.

[48] Committee on Climate Change (2008) *Building a low-carbon economy: the UK's contribution to tackling climate change*, available at: http://www.theccc.org.uk/pdf/TSO-ClimateChange.pdf, p415.

[49] Watson J (2009) Is the move toward energy security at odds with a low-carbon society?, in *Building a low-carbon future: the politics of climate change*, Giddens A, Latham S and Liddle R (Editors) (London: Policy Network), pp35–6.

1.12 Many debates focus almost exclusively on the first of these risks, particularly on concerns that supplies of cheap oil are dwindling, while growing global demand has led to rising oil prices. A recent review of the evidence from the UK Energy Research Centre recognises that there continues to be significant debate regarding the timing of a peak in global oil production. It nevertheless suggests that "a peak of conventional oil production before 2030 appears likely and there is a significant risk of a peak before 2020".[50] The International Energy Agency (IEA) has changed its position on this issue, concluding recently that there is a real risk of a near-term global "oil-supply crunch" due to under-investment.[51] Given the expectation of continually rising future demand for transport fuel, the envisaged negative effect of such an 'oil crunch' on the transport fuel sector is lending some urgency to the search for alternative fuels – with biofuels a promising candidate from this perspective.

1.13 Access to energy by consumers depends not only on the availability of fuels, but also on timely investment in infrastructure such as power stations, refineries, transmission lines, gas grids and storage facilities. With regard to the transport sector, some biofuels might require investment in new infrastructure, while others, in particular biodiesel, could be produced, distributed and used within existing fuel infrastructure.

1.14 Technical failures due to faults or external stresses, such as extreme weather, are a feature of all large infrastructure systems, including those that supply our energy needs. If they become widespread, the consequences can be serious. Recent events such as the BP oil spill or Hurricane Katrina, and their impacts on the operation of offshore oil and gas facilities in the Gulf of Mexico, show that these risks need to be taken seriously. In comparison with offshore drilling for fossil fuels, biofuels might present fewer risks: spills are far less toxic. However, extreme weather can of course still impact on crop yields and destroy harvests. This in turn can decrease the availability of feedstocks and drive up prices of biofuels.

1.15 Threats due to industrial activism and terrorism are now an increasing feature of energy security discussions. Historically speaking, non-fossil energy sources, such as renewable fuel and energy sources, have been less vulnerable to such dangers, but, again, parts of the energy infrastructure such as pipelines, tankers and storage facilities could be vulnerable to terrorist attack. In principle, such risks also apply to biofuels, in particular to those which could be produced and distributed using established fuel infrastructure. However, there is the potential to produce some biofuels in a more decentralised way than traditional fossil fuel production, thus contributing to a lower degree of vulnerability of the production chain to terrorist activity. Some commentators also stress the value of such diversification in fuel production for national security purposes. One respondent to our consultation stated: "…if we value military strategic flexibility and understand that our reserves of fossil fuels soon will not be adequate to produce the energy needed…, then we must find ways to develop the fuel from other means...".[52]

Energy security in the UK: issues and policy responses

1.16 After about two decades as a net exporter of oil and gas, the UK has recently become a net energy importer again. In his 2009 report, Malcolm Wicks MP, then Special Representative on International Energy to the Prime Minister, proposed a UK strategy to supply energy for the transport and other sectors that would still enable the UK to achieve its climate change

[50] UK Energy Research Centre (2009) *The global oil depletion report*, available at: http://www.ukerc.ac.uk/support/tiki-index.php?page=Global+Oil+Depletion, px.
[51] International Energy Agency (2008) *World energy outlook: executive summary*, available at: http://www.worldenergyoutlook.org/docs/weo2008/WEO2008_es_english.pdf, p7.
[52] Advanced Biofuels USA, responding to the Working Party's consultation.

objectives.[53] It proposed "a framework in relation to both international and domestic policy of first, acting to reduce total energy demand; secondly, promoting the adoption of technologies that reduce reliance on oil and gas and simultaneously reduce GHG emissions; and, finally, acting to mitigate the international energy security risks inherent in the use of fossil fuels".[54] Biofuels, produced domestically, could score high on the two latter goals.

1.17 As with many reports on energy security, the report by Malcolm Wicks MP offers a partial view of the subject. However, a key strength is that there is a strong emphasis on diversity. A diverse mix of (i) energy sources and technologies in the different energy sectors, (ii) sources and supply routes of individual fuels, and (iii) distribution and stocking infrastructures can all help to minimise risks to energy security. In his report, Malcolm Wicks MP gives one view of specific energy options that he feels will strengthen diversity. However, it is important to remember that this is open to debate: diversity is a property of the energy system as a whole and views vary on the extent to which individual energy technologies or sources add to that diversity.[55]

Energy security and biofuels

1.18 In 2007, fuel for transport accounted for 27 per cent of total world delivered energy consumption.[56] In the same year, 53 per cent of liquid fuel supplied was consumed by the transport sector, and this proportion is predicted to rise to 61 per cent by 2035.[57] We have stressed before that it is vital to reduce consumption significantly over the next few decades. However, it is unrealistic to expect that the demand for liquid transport fuels will reduce significantly. Petroleum products are very convenient fuels owing mainly to their relatively high energy density.[58] Furthermore, engine and fuel development have occurred symbiotically over a long period of time resulting, technically and economically, in highly effective combinations for transport, integrally linked to a global production and distribution system. Vehicles with new types of engine which use completely different fuels or sources of energy, such as electric cars,[59] not only require research, development, demonstration and deployment, but also investment in supporting infrastructure and refuelling networks. This is a major consideration for road transport systems and is even more challenging for air transport where there are currently almost no alternatives to engines which rely on relatively high energy-density liquid fuels.[60]

1.19 The UK will therefore continue to rely heavily on imports. With the high percentage of liquid fuel used for transport in the UK, there is a strong interest in having a constant and affordable

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53 Wicks M (2009) *Energy security: a national challenge in a changing world*, available at: http://www.decc.gov.uk/assets/decc/What%20we%20do/Global%20climate%20change%20and%20energy/International%20energy/energy%20security/1_20090804164701_e_@@_EnergysecuritywicksreviewBISR3592EnergySecCWEB.pdf.

54 Wicks M (2009) *Energy security: a national challenge in a changing world*, available at: http://www.decc.gov.uk/assets/decc/What%20we%20do/Global%20climate%20change%20and%20energy/International%20energy/energy%20security/1_20090804164701_e_@@_EnergysecuritywicksreviewBISR3592EnergySecCWEB.pdf, p5.

55 Stirling A (2010) Multicriteria diversity analysis: a novel heuristic framework for appraising energy portfolios *Energy Policy* **38**: 1622–34.

56 US Energy Information Administration (2010) *International energy outlook 2010: world energy demand and economic outlook*, available at: http://www.eia.doe.gov/oiaf/ieo/world.html. This comprises the energy used in moving people and goods by road, rail, air, water and pipeline.

57 US Energy Information Administration (2010) *International energy outlook 2010: liquid fuels*, available at: http://www.eia.doe.gov/oiaf/ieo/liquid_fuels.html, Figure 31.

58 Energy density: energy available per unit volume or weight of fuel. High energy density reduces the amount of fuel storage required in the vehicles that they power. It also helps to reduce the deadweight of the vehicle (vehicle weight including engine(s) and fuel) relative to its payload (passengers and/or freight), thereby increasing its overall energy performance (number of passengers or tonnes of freight carried each kilometre per unit of fuel consumed).

59 For road transport, alternatives to current systems include electric vehicles with battery storage and fuel cell vehicles which use hydrogen.

60 For example, the 2009 report on aviation by the CCC concluded that there were significant technical and logistical barriers to the use of hydrogen-fuelled aircraft. Additionally, the climate impacts needed to be more clearly understood before the concept was pursued; see: Committee on Climate Change (2009) *Meeting the UK aviation target – options for reducing emissions to 2050*, available at: http://downloads.theccc.org.uk/Aviation%20Report%2009/21667B%20CCC%20Aviation%20AW%20COMP%20v8.pdf, pp115–8.

supply of transport fuels for strategic and operational economic reasons to avoid price volatility and restricted economic growth.[61] Hence, the possibility of deriving liquid fuels from locally grown sources and using them as alternatives to petroleum products in existing engines for all forms of transport is extremely attractive. This is the basis of initial interest in biofuels derived from biomass that can be a renewable source of energy.

1.20 Biofuels from biomass, which can be grown domestically or abroad, could improve diversity within the UK's transport fuel mix. In 2009, the UK Renewable Energy Association concluded that there is sufficient availability of sustainable feedstock for biofuel demand in both the EU and the UK to meet targets[62] (as set by the Renewable Energy Directive (RED), discussed below).[63]

1.21 Biofuels have been highlighted as a potentially important contribution to future energy supply in many recent reports concerned with energy security.[64] In its 2007 report, the IEA in particular stresses that: "Biofuels for transport represent a key source of diversification from petroleum."[65] Indeed, countries such as Brazil implemented their large-scale biofuels programmes mainly owing to worries over energy security and dependence on oil-based fuels (see Chapter 2).

1.22 The expectation that biofuels can contribute significantly to energy supply diversification is reflected in recent UK energy policy, where the Government's goal, under The Renewable Transport Fuel Obligations (Amendment) Order 2009, is for 5 per cent of total transport fuel to originate from renewable sources by 2013.[66] This may sound like a small contribution, but even a small contribution could be quite important in the energy portfolio of the future. However, as with other potential sources of energy for the future, the security benefits of biofuels will need to be analysed carefully. This analysis will need to consider not only fuel diversity, but also the sources of biofuels (e.g. geographical locations), the supply routes to and within the UK, and the resilience of infrastructure within the UK for stocking and local distribution. It will also need to consider whether other complementary or alternative ways of meeting the demand for transport could be more or less secure than a mix that includes biofuels. Finally, energy security concerns need to be integrated with other motivations, such as climate change mitigation and the need to preserve ecosystem services. In the following chapters, we offer some guidance on how to engage in this discussion.

Economic development

> **"The most important factor in driving the development of biofuels in the future will be the need for promoting agricultural and economic development with millions, perhaps billions of farmers around the world, living in marginal areas, facing a lack of resources, especially**

61 Beyond the transport sector, fuel price volatility has become a concern because price spikes contribute to fuel poverty.

62 Renewable Energy Association (2009) *REA position paper on the UK's implementation of the renewable transport elements of the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD)*, available at: http://www.r-e-a.net/document-library/policy/policy-briefings/0906%20REA%20position%20paper%20on%20RED-FQD%20implementation%20FINAL.pdf, p4.

63 Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16.

64 Wicks M (2009) *Energy security: a national challenge in a changing world*, available at: http://www.decc.gov.uk/assets/decc/What%20we%20do/Global%20climate%20change%20and%20energy/International%20energy/energy%20security/1_20090804164701_e_@@_EnergysecuritywicksreviewBISR3592EnergySecCWEB.pdf, pp74–5; International Energy Agency (2007) *Contribution of renewables to energy security*, available at: http://www.iea.org/papers/2007/so_contribution.pdf, p63.

65 International Energy Agency (2007) *Contribution of renewables to energy security*, available at: http://www.iea.org/papers/2007/so_contribution.pdf, p5.

66 Art 4 of The Renewable Transport Fuel Obligations Order 2007 amended by The Renewable Transport Fuel Obligations (Amendment) Order 2009. This could also include other renewable sources, for example electric vehicles powered by electricity from renewable sources such as solar or wind.

energy…Addressing the needs of these people must be the driving force for promoting bioenergy development efforts.”[67]

“It is my contention that the production of biofuels has contributed little to reducing poverty. There are far more efficient and effective ways of achieving this goal than through the promotion of biofuels.”[68]

Introduction

1.23 Supporting economic development is an important goal of most modern societies in order to improve the wealth and well-being of their citizens. It is of particular concern in developing and emerging nations, which generally experience greater levels of poverty and lower standards of living. Patterns of industrialisation have to date been energy intensive. If emerging and less developed economies follow the established technological and economic paths of development, a global energy and environmental crisis will be inevitable. Energy and fuel consumption in emerging economies, such as Brazil and China, have risen steeply owing to advances in industrialisation and, as described in the Introduction (paragraph 5), are expected to continue to rise.

1.24 In developing countries, which are more vulnerable to changes of climate than the developed world, concerns about environmental security are especially relevant when further economic development is considered. This is mirrored in the United Nations (UN) Millennium Development Goals. The Millennium Development Goals link development and the protection of the environment explicitly together. For example, Goal 7 is titled: “Ensure environmental sustainability”, while the corresponding Target 7A[69] (“Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources”) and Target 7B (“Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss”) are recognised as vital contributing elements of this Goal.[70] To enable development without further jeopardising the climate and environment, investment in alternative energies including biofuels can appear very attractive.

Economic development and agricultural policy

1.25 The development of biofuels policy, for example in Canada, in the US and in the EU, has important intersections with agricultural policy. For example, in the EU the Common Agricultural Policy (CAP) was reformed in 1992, effectively allowing non-food crops to be grown on set-aside land – land which was quickly earmarked as land for biofuels production.[71] In 2003, a new payment was granted which paid farmers additional amounts for biofuels crops grown.[72] The EC also authorised EU Member States to grant tax relief to biofuels to make growing biofuels crops more attractive to farmers.[73]

1.26 These interactions between policies increase the challenges in evaluating their performance and raise questions about who will benefit from expansion in biofuels production. A report by the German Marshall Fund of the United States shows that some trade policies adopted by developed countries inhibit the extent to which developing countries can benefit from this expansion, by limiting their biofuels export potential.[74] Such policies include tariffs and

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[67] Bernardo Ospina, responding to the Working Party’s consultation.
[68] Dr Ben Richardson, responding to the Working Party’s consultation.
[69] In the Millennium Development Goals, each goal is subdivided into several targets.
[70] United Nations (2010) *Millennium Development Goals: Goal 7 – ensure environmental sustainability*, available at: http://www.un.org/millenniumgoals/environ.shtml.
[71] Library of Parliament (Canada) (2007) *Biofuels – an energy, environmental or agricultural policy?*, available at: http://www2.parl.gc.ca/content/lop/researchpublications/prb0637-e.pdf, p3.
[72] Europa (22 Sept 2006) *Renewable energy: Commission proposes to extend energy crop aid scheme to all Member States*, available at: http://europa.eu/rapid/pressReleasesAction.do?reference=IP/06/1243.
[73] Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16, art 2.k and 3.a.
[74] German Marshall Fund of the United States (2007) *EU and U.S. policies on biofuels: potential impacts on developing countries*, available at: http://www.gmfus.org/galleries/ct_publication_attachments/GMF_USEU_Final.pdf;jsessionid=abF8P5gT_Lt8I9EWS3, pp21–4.

subsidies to protect and support domestic markets. Technical norms relating to biofuels that are enshrined in policy can also have a limiting effect. Indeed, it has been suggested elsewhere that countries of the Organisation for Economic Co-operation and Development (OECD) need to reduce agricultural support regimes for biofuels to avoid limiting developing countries, which already have restricted access to OECD markets.[75]

Economic development, energy security and biofuels

1.27 Uncertainty, both about the projected impact of fossil fuels on climate change and the role which new technologies can play in providing viable alternatives, has led governments and companies to invest in energy portfolios so that investment risks are balanced across a number of new technologies, including biofuels. In addition, there is the expectation that investment in biofuels will lead to significant benefits in economic development, including the creation of new jobs and new areas of income for farmers. An early powerful incentive for biofuels in the US was significant agricultural overproduction, which led to enthusiasm to use food crops for so-called first generation biofuels. Biofuels production might also be a very attractive prospect particularly in poor countries and those in which a large proportion of the population engages in agriculture. For example, in some of the new EU Member States, such as Poland, primary agricultural productivity is relatively low on account of CAP, and it has been suggested that growing crops in these countries for some of the new biofuels could contribute significantly to economic development.[76] This in turn could afford benefits for infrastructure development and income creation. As for the UK, new biofuels which are currently under development might present a number of opportunities for economic development of rural areas, offering new avenues for both business and farmers. In 2009, the then Minister for Science and Innovation, Rt Hon Lord Drayson, said, upon launching the Biotechnology and Biological Sciences Research Council Sustainable Bioenergy Centre, the UK's biggest public investment in bioenergy research, that the centre was: "a great example of the UK investing in innovative areas which have the benefits of creating new green collar jobs".[77]

1.28 Moreover, biofuels are expected to provide cheaper energy made from locally available sources. This can be particularly important in developing countries where successful industrialisation has increased the demand for energy. In many developing countries there is a lack of indigenous energy sources, restricted access to affordable energy supplies, fragile energy infrastructure and inefficiency in energy utilisation. There is a potential, therefore, for poorer countries, which are often those countries that are expected to play a key role in growing biofuels in the future, to make developmental gains and to provide local sources of energy for the necessities of everyday life. As one respondent to our consultation put it:

> **"In many regions of the world, especially in Sub-Saharan Africa, Asia, and many parts of Latin America, many smallholder communities do not have any access to any type of energy…in many of these regions, bioenergy crops could be produced and transformed into biofuels that can be used as the first step towards processes at community level to generate bio-electricity, use clean-cook stoves, introduce mechanisation, and other technologies."**[78]

[75] Overseas Development Institute (2007) *Biofuels, agriculture and poverty reduction*, available at: http://www.odi.org.uk/resources/download/78.pdf, p1.

[76] EuropaBio, responding to the Working Party's consultation.

[77] Biotechnology and Biological Sciences Research Council (27 Jan 2009) *Biggest ever public investment in bioenergy to help provide clean, green and sustainable fuels*, available at http://www.bbsrc.ac.uk/news-test/archive/2009/090127-pr-public-investment-bioenergy.aspx.

[78] Bernardo Ospina, responding to the Working Party's consultation.

Other hopes for biofuels in countries where industrialisation strategies have not been so successful revolve around:

- the creation of employment and income;
- diversification of energy supply, especially where countries obtain a large proportion of their energy from the increasingly unstable global oil market;[79]
- diversification of agricultural output and added security of income from local agriculture; and
- increased national exports leading to greater involvement in global economic activity.

Indeed, several developing countries and emerging nations, such as Mozambique, India and China, have established biofuels strategies with some of these goals in mind.[80]

1.29 Such national energy strategies aiming to feed industrial development may of course be destabilising globally. Globalisation has led to multiple and extensive interdependencies and this means that national strategies can have broader impacts. The role of biofuels within an energy provision framework is therefore highly complex. Global economic development, particularly in non-OECD emerging economies, will increase global energy demand. Most of this growth to 2035 will be fossil fuel led, but biofuels could offer an opportunity to provide fuel for transport with the potential additional advantages of energy security, environmental sustainability and a lower carbon footprint. It is not surprising that some commentators, at least initially, regarded biofuels as a one-stop shop for developing countries on their way towards industrialised levels of development and consumption.

Climate change

"[Increased use of biofuels] is an essential part of our response to climate change. We have no other carbon neutral alternative options for transport fuels for planes and heavy vehicles."[81]

"Industrial biofuels exacerbate climate change and destroy ecosystems such as rainforests that regulate our weather patterns."[82]

Introduction

1.30 Over the last few decades, awareness of the potential consequences of climate change (see Box 1.2) has grown considerably. Although there is some dispute within the scientific community regarding the time frame, magnitude and impacts of climate change,[83] most climate scientists have concluded that it will have severe social, economic and environmental

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79 UN-Energy (2007) *Sustainable bioenergy: a framework for decision makers*, available at: http://esa.un.org/un-energy/pdf/susdev.Biofuels.FAO.pdf. For details of impacts of small-scale bioenergy initiatives on livelihoods (for example, with regard to financial capital and social capital impacts) see: Practical Action Consulting (2009) *Small-scale bioenergy initiatives: brief description and preliminary lessons on livelihood impacts from case studies in Asia, Latin America and Africa. Prepared for PISCES and FAO by Practical Action Consulting*, available at: ftp://ftp.fao.org/docrep/fao/011/aj991e/aj991e.pdf.

80 See: International Centre for Trade and Sustainable Development (17 April 2009) *Mozambique approves policy on biofuels*, available at: http://ictsd.org/i/news/biores/45169/; Press Information Bureau, Government of India (24 Dec 2009) *National policy on bio-fuels announced*, available at: http://pib.nic.in/release/release.asp?relid=56469; National Development and Reform Commission (2007) *Medium and long-term development plan for renewable energy in China*, available at: http://www.asiapacificpartnership.org/pdf/REDGTF/4th_meeting/China-_Medium_and_Long-Term_Development_Plan.pdf, p5.

81 Robert Henry, responding to the Working Party's consultation.

82 Food Not Fuel, responding to the Working Party's consultation.

83 Climate change as discussed today, involving rising average global temperatures, is often misleadingly referred to as 'global warming'. However, impacts on individual geographic locations are likely to vary widely and go further than increases in average temperature.

effects globally. Climate change has entered public debates and popular culture, and polls show that it is now a pressing concern of today's populations.[84]

Box 1.2: Defining climate change

The Intergovernmental Panel on Climate Change defines climate change as: "a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity."[85] The UN Framework Convention on Climate Change (UNFCCC) describes climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."[86] Causes of climate change beyond human control are, for example, variations in solar radiation, deviations in the Earth's orbit, and changes in the Earth's plate tectonics. Important factors of human origin include the emission of GHGs, primarily through fossil fuel combustion, and the destruction of environments that absorb and store carbon from the atmosphere (carbon sinks), such as forestland and peatland.

International climate change mitigation policy

1.31 Climate change mitigation is now recognised as one of the great global challenges of the 21st century. There is still debate over who is responsible – both politically and financially – for climate change mitigation, including how it can best be achieved and how a global mitigation effort can best be orchestrated. However, there is a general consensus that lowering GHG emissions is one of the most important strategies in tackling climate change. At the same time, there is increasing pressure, particularly from vulnerable developing countries, for the international policy process to place more emphasis on adaptation to the climate change that is already likely to occur.

1.32 International policy reflects the consensus to limit GHG emissions in order to mitigate climate change, while at the same time highlighting the challenges of transnational, binding agreements. Following the UNFCCC in 1992,[87] the Kyoto Protocol[88] to the UNFCCC was adopted in 1997. There are currently 193 parties to the Kyoto Protocol, and a further 84 signatories.[89] The Kyoto Protocol is the first international treaty on climate change and includes legally binding GHG emission targets. It aims at the stabilisation of "aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in [the Protocol]", and commits 40 industrialised countries and countries with economies in transition (so-called 'Annex I' countries) to lower their GHG emissions "by at least 5 per cent below 1990 levels" by 2012.[90]

1.33 Since the ratification of the Kyoto Protocol in 2005, negotiations over long-term action on climate change have continued under the UNFCCC. The landmark Copenhagen conference in December 2009 attracted worldwide attention but failed to agree a new framework for action beyond the expiry of the current phase of Kyoto in 2012. The most recent Conference of the Parties to the UNFCCC in Cancun, Mexico, was held a year later. While it only made

84 BBC World Service (7 Dec 2009) *Climate concerns continue to increase according to global poll*, available at: http://www.bbc.co.uk/pressoffice/pressreleases/stories/2009/12_december/07/poll.shtml.
85 Intergovernmental Panel on Climate Change (2007) *Climate change 2007: synthesis report*, available at: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf, p30.
86 United Nations (1992) *United Nations Framework Convention on Climate Change*, available at: http://unfccc.int/resource/docs/convkp/conveng.pdf, art 1.
87 United Nations (1992) *United Nations Framework Convention on Climate Change*, available at: http://unfccc.int/resource/docs/convkp/conveng.pdf, art 2.
88 Kyoto Protocol to the United Nations Framework Convention on Climate Change 1998.
89 United Nations Framework Convention on Climate Change (2011) *Status of ratification of the Kyoto Protocol*, available at: http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php. Notably, the US is only a signatory to the Kyoto Protocol.
90 Kyoto Protocol to the United Nations Framework Convention on Climate Change 1998, art 3.1.

incremental progress, it resulted in a number of officially recognised Cancun Agreements and a restoration of some faith in the UN negotiations.

1.34 The Cancun Agreements stress that deep cuts in global GHG emissions are urgently required and that all countries should: "cooperate in achieving the peaking of global and national greenhouse gas emissions as soon as possible".[91] It acknowledges that the timescale for emissions reductions will be longer for developing countries, and that the main priorities are: "social and economic development and poverty eradication".[92] The Agreements do not contain any legally binding commitments for reducing GHG emissions beyond the first commitment period of the Kyoto Protocol (2008–2012). However, they do include important commitments on key issues such as finance, technology assistance and the reduction of emissions from deforestation and forest degradation. For example, developed countries have pledged to make available 100 billion USD a year by 2020 for developing countries, and all Parties have agreed to the establishment of a new Climate Technology Centre and Network.

UK climate change policy and targets

1.35 The UK currently has one of the most ambitious national climate change programmes in the world. In 2003, the UK Energy White Paper proposed to put the UK on a path to cut its carbon dioxide emissions by some 60 per cent by about 2050 relative to 1990 levels.[93] However, when the Climate Change Act 2008 was passed, it mandated that the net UK carbon account for the year 2050 be at least 80 per cent lower than the 1990 baseline,[94] following the suggestion of the CCC, which became a statutory committee when the Climate Change Bill became law.[95] The majority of the measures contained in the Energy Bill[96] – introduced into Parliament in late 2010, and, at the time of press, still passing through Parliament – aim to make provision for energy efficiency measures to be applied to both homes and businesses. The Energy Bill is also designed to enable and secure low carbon energy supplies.

EU climate change policy and targets

1.36 The EU speaks for its Member States in international climate negotiations and so UK climate change policies and targets, including the biofuels and renewables policies/targets, stem in part from the EU. In 2007, EU leaders endorsed an integrated approach to climate and energy policy, and made a commitment to transform Europe into a highly energy efficient and low carbon economy. To start the process, the leaders set a package of targets to be met by 2020, collectively known as the '20-20-20' targets. These are:[97]

- a reduction in EU GHG emissions of at least 20 per cent below 1990 levels by 2020;
- 20 per cent of EU energy consumption to come from renewable sources by 2020; and

91 United Nations Framework Convention on Climate Change (2010) *Outcome of the work of the Ad Hoc Working Group on long-term cooperative action under the Convention*, unedited version, available at: http://unfccc.int/files/meetings/cop_16/application/pdf/cop16_lca.pdf.
92 Ibid.
93 Department of Trade and Industry (2003) *Our energy future – creating a low carbon economy*, available at: http://www.berr.gov.uk/files/file10719.pdf, p8.
94 s1(1) Climate Change Act 2008. The '1990 baseline' meant the aggregate amount of net UK emissions of carbon dioxide, methane and nitrous oxide for 1990, and the net UK emissions of hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride for 1995.
95 Committee on Climate Change (2008) *Building a low-carbon economy – the UK's contribution to tackling climate change*, available at: http://www.theccc.org.uk/pdf/TSO-ClimateChange.pdf, pv. The CCC has subsequently been critical of Government about the lack of progress towards this long-term target. Its most recent stated that emission reductions in recent years had been very modest, and going forward there needed to be a 'step change' if the UK's targets between now and 2050 were to be achieved; see: Committee on Climate Change (2009) *Meeting carbon budgets: the need for a step change*, available at: http://hmccc.s3.amazonaws.com/21667%20CCC%20Report%20AW%20WEB.pdf, p29.
96 Parliament UK (2011) *Energy Bill [HL] 2010–11*, available at: http://services.parliament.uk/bills/2010-11/energyhl.html.
97 European Commission (2010) *The EU climate and energy package*, available at: http://ec.europa.eu/environment/climat/climate_action.htm.

- a 20 per cent reduction in primary energy use compared with projected levels by 2020, to be achieved by improving energy efficiency.

Binding legislation to implement the 20-20-20 targets was agreed by the European Parliament and Council in December 2008 and became law in June 2009. This 'climate and energy package' also led to the new RED (see below).[98] Tensions remain among EU Member States about the desirability of such increased targets.

Climate change and biofuels

1.37 National and international policy documents on climate change mitigation stress that there are several routes to lowering GHG emissions, all of which will have to be pursued aggressively in order to achieve successful climate change mitigation. In particular, each sector of the economy will have to make significant contributions to deep carbon cuts in a relatively short timescale (before 2050). Such a demanding requirement is particularly challenging for the transport sector, because its demand is fairly inelastic and any economy-wide policy tool that aims to reduce GHG emissions, such as a tax on GHG emissions, will result in little reduction in the transport sector.[99] In 2008, transport was responsible for 22 per cent of the global carbon dioxide emissions produced from fuel combustion.[100] In the UK in 2009, transport accounted for an estimated 22 per cent of total GHG emissions.[101] Between 1990 and 2002, emissions from transport in OECD countries and non-OECD countries increased by 25 per cent and 36 per cent respectively.[102] In a 'business as usual' scenario,[103] this rate of increase is expected to continue into the foreseeable future. Hence, the magnitude of required emissions reductions for this sector is very substantial, in absolute terms.

1.38 Widespread commercial replacement in the transport sector in a relatively short timescale with vehicles that do not rely on traditional fossil fuels and have significantly lower GHG emissions will be very demanding. As mentioned above, the large-scale introduction of vehicles with new types of engine that use completely different fuels or sources of energy is challenging, particularly in the aviation sector. Developing alternative fuels that do not require changes in vehicle technology and have the potential to reduce transport's carbon footprint is attractive, and biofuels are expected to deliver on both these counts.

1.39 It has been asserted that: "Biofuels are considered 'carbon-neutral' when burned" (see Box 1.3),[104] since on combustion they release only the carbon dioxide that was absorbed during the plant's growth.[105] For this reason, they have been heralded as an immediately available technology that might generate significant GHG emissions savings. Recently, provisional data were reported which suggested that the amount of biofuels supplied in the UK during 2009–2010 generated GHG emissions savings "equivalent of taking half a million vehicles off the

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98 Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16.

99 A tax would create more savings in other sectors, such as from coal consumption.

100 International Energy Agency (2010) *CO_2 emissions from fuel combustion: highlights*, available at: http://www.iea.org/co2highlights/co2highlights.pdf, p9.

101 Department of Energy and Climate Change (2011) *UK climate change sustainable development indicator: 2009 greenhouse gas emissions, final figures*, available at: http://www.decc.gov.uk/assets/decc/Statistics/climate_change/1214-stat-rel-uk-ghg-emissions-2009-final.pdf, p3.

102 HM Treasury and Cabinet Office (2006) *Stern Review: the economics of climate change*, available at http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/sternreview_index.htm, Annex 7c.

103 This includes any incremental improvements in fuel efficiency and the switch to biofuel that would be expected to occur even in the absence of policy intervention.

104 Parliamentary Office of Science and Technology (2007) *Transport biofuels*, available at: http://www.parliament.uk/documents/post/postpn293.pdf.

105 That these biogenic GHG emissions are reported as zero is based on the United Nations Framework Convention on Climate Change.

road, or making Edinburgh, Cardiff and Belfast car free".[106] Next to expectations of increased energy security and further economic development, this hope has underpinned biofuels policy as it has developed over the last decade.

Box 1.3: What is carbon neutrality?[107]

'Carbon neutral' refers to a state where the carbon dioxide produced by a process or person is balanced by the amount of carbon dioxide sequestered out of the atmosphere or offset by that process or person.[108] In the context of biofuels, this concept is usually introduced in relation to the claim that there is a balance in carbon dioxide between absorption during the growth of the biomass and emissions during combustion of the fuel. However, such calculations also need to take into account total GHG emissions from the full life cycle of biofuels production, including provision and processing as well as any land use change involving the destruction of a carbon stock.

Current biofuels policy

1.40 Policy, looking to reap the expected benefits of biofuels in all three areas of interest, has been instrumental in supporting and steering biofuels development. As part of a rapidly developing field of policy making, a multitude of different policy instruments has been introduced over the last decade in the UK, Europe and worldwide.

1.41 At the European level, mandated markets have been established. The EC passed the Biofuels Directive in 2003, which specified that biofuels and other renewable fuels must account – on the basis of energy content – for 5.75 per cent of all transport petrol and diesel by 31 December 2010.[109] A 2007 Communication from the EC later evaluated the share of renewable energy in the energy mix and the progress in this area. It proposed that the minimum target for biofuels for 2020 should be 10 per cent of transport petrol and diesel.[110] This target was subsequently mandated in the RED of 2009, which repealed the Biofuels Directive.[111] In 2009, the Fuel Quality Directive also required Member States to reduce life cycle GHG emissions of transport fuels by 6 per cent by the end of 2020, which has indirectly affected biofuels markets.[112] More European biofuels policy can be found in Box 1.4.

Box 1.4: Additional European biofuels policy

Several other European policy instruments have supported biofuels production. For example, the Energy Crops Scheme was introduced in 2003 and extended to all Member States in 2006.[113] This pays farmers 45 euros per hectare of land that is used for growing energy crops for biofuels. The scheme has been very successful: by 2007, it accounted for 60 per cent of the European domestic supply of biofuel crops.[114] The EC published its EU Strategy for Biofuels in 2006,[115] outlining seven policy axes to: stimulate demand for biofuels; capture environmental benefit; develop the production and

[106] BBC News (31 Aug 2010) *UK biofuels 'falling short' of environmental standards*, available at: http://www.bbc.co.uk/news/science-environment-11112837.

[107] Carbon Carbon (2011) *What does carbon neutral mean? Is there a war on?*, available at: http://www.carboncarbon.co.uk/cneutral.html.

[108] It may be helpful to add that PAS 2060, a new standard on carbon neutrality published by BSI, the national standards body of the UK, sets out guidance on how to quantify, reduce and offset GHG emissions from a specific subject, ranging from events to products. The standard is not specifically designed for biofuels; it is intended for demonstration of carbon neutrality status.

[109] Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport [2003] OJ L123/42, art 1(b)(ii).

[110] European Commission (2007) *Renewable energy road map: renewable energies in the 21st century: building a more sustainable future*, available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0848:FIN:EN:PDF, p10.

[111] Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16, art 3.4.

[112] Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC [2009] OJ L140/88, art 7(a).

[113] Europa (22 Sept 2006) *Renewable energy: Commission proposes to extend energy crop aid scheme to all Member States*, available at: http://europa.eu/rapid/pressReleasesAction.do?reference=IP/06/1243.

[114] Ninni A (2010) Policies to support biofuels in Europe: the changing landscape of instruments *AgBioForum* **13**: 131–41.

[115] European Commission (2006) *An EU strategy for biofuels*, available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0034:FIN:EN:PDF.

distribution of biofuels; expand biofuels sources supplies; enhance trade opportunities; support developing countries; and support research and development. In 2007, the EC introduced the SET-Plan[116] with the aim of accelerating the development and use of cost-effective low carbon technologies, including new biofuels. In its 2009 resolution *2050: The future begins today – recommendations for the EU's future integrated policy on climate change*, the European Parliament called on the EC and the Member States to increase research and development for advanced biofuels, to ensure that they were allocated necessary funding.[117] Furthermore, it called for the promotion of the development of a global biofuels standard, drawing on previous experience of developing sustainability criteria. Also in 2009, legislation was enacted to protect European biodiesel producers. The EC published a Regulation imposing a provisional 'anti-dumping' duty on biodiesel imports from the US,[118] following concerns that the European biodiesel industry was competing with unfairly subsidised and dumped US biodiesel exports.

1.42 In the UK, following European policy, the Renewable Transport Fuel Obligations (RTFO) Order 2007 placed an obligation on fossil fuel suppliers to ensure that a certain percentage of their transport fuel supplied in the UK was made up of renewable fuels each year. The RTFO Order came into effect in April 2008 and stated that 5 per cent of road vehicle fuel supplied in the UK must come from renewable sources by 2010.[119] Following the Gallagher Review,[120] which was a review commissioned by the UK Government, the RTFO (Amendment) Order 2009[121] reset the 5 per cent target to be reached by 2013. The RTFO Order also represents policy intended to address the sustainability of biofuels, in that it requires fuel suppliers to submit reports on the GHG emissions and sustainability of biofuels. The Renewable Fuels Agency (RFA)[122] is the organisation charged by the UK Government with running the RTFO, ensuring that companies meet their annual obligations. The RFA runs the carbon and sustainability reporting system and is also the UK's independent sustainable fuel regulator.

1.43 Support for biofuels manufacturers in the UK has led to stimulation of biofuels production. A 20 pence per litre duty differential was introduced for biodiesel in July 2002[123] and bioethanol in 2005.[124] These duty differentials were abolished in April 2010 for all biofuels except biodiesel produced from used cooking oil, which would continue to benefit from a 20 pence duty differential for a further two years.[125] The UK's *Budget 2003* also outlined steps to introduce a new lower rate of vehicle excise duty (the tax commonly known as road tax) for the most environmentally friendly cars with very low levels of carbon dioxide emissions,[126] thus incentivising purchase of cars that run on biofuels. The Low Carbon Vehicle Procurement Programme – announced in the Energy White Paper of May 2007 – exists to provide funding to public sector organisations to procure innovative, low carbon vehicles.[127]

116 European Commission (2007) *A European strategic energy technology plan (SET-Plan): 'towards a low carbon future'*, available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0723:FIN:EN:PDF.

117 European Parliament (2009) *European Parliament resolution of 4 February 2009 on "2050: the future begins today – recommendations for the EU's future integrated policy on climate change"*, available at: http://www.biofuelstp.eu/downloads/040209_resolution_ep_climate_change.pdf, p20.

118 Commission Regulation (EC) No 193/2009 of 11 March 2009 imposing a provisional anti-dumping duty on imports of biodiesel originating in the United States of America [2009] OJ L67/22.

119 The Renewable Transport Fuel Obligations Order 2007, art 4.

120 Renewable Fuels Agency (2008) *The Gallagher Review of the indirect effects of biofuels production*, available at: http://www.renewablefuelsagency.gov.uk/sites/renewablefuelsagency.gov.uk/files/_documents/Report_of_the_Gallagher_review.pdf.

121 Art 4 of The Renewable Transport Fuel Obligations Order 2007 amended by The Renewable Transport Fuel Obligations (Amendment) Order 2009.

122 Renewable Fuels Agency (2010) *About us*, available at: http://www.renewablefuelsagency.gov.uk/abouttherfa.

123 HM Treasury (2002) *Budget 2002*, available at: http://webarchive.nationalarchives.gov.uk/20100407010852/http://www.hm-treasury.gov.uk/bud_bud02_chapter_7.htm, paragraph 7.30.

124 HM Treasury (2003) *Budget 2003*, available at: http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/d/Budget_2003.pdf, paragraph 7.28.

125 HM Revenue & Customs (2010) *Excise duty: relief scheme for biodiesel produced from waste cooking oil*, available at: http://www.hmrc.gov.uk/briefs/excise-duty/brief1810.htm.

126 HM Treasury (2003) *Budget 2003*, available at: http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/d/Budget_2003.pdf, paragraph 7.32.

127 Low Carbon Vehicle Procurement Programme (2010) *The Low Carbon Vehicle Procurement Programme*, available at: http://www.lcvpp.org.uk/.

1.44 As regards the priority of using biomass, these could currently be described as follows in the UK: the first priority is to use biomass for electricity generation (to meet the Renewables Obligation),[128] then for biofuels (to meet the RTFO), and lastly for heat (including combined heat and power generation), where we are still waiting for the details of the Renewable Heat Incentive.[129]

Impact of current and future drivers for biofuels production

1.45 Three reasons for the development of biofuels as an alternative to fossil fuels have been described here. The attractiveness to politicians, farmers and some companies of developing current biofuels can be explained by their apparent ability to meet three important policy objectives with a single solution – the elusive silver bullet of energy security, economic development and climate change mitigation.

1.46 Alas, as the next chapter will show, biofuels are no perfect solution. Warning voices were raised from an early stage about their potential problems.[130] The efforts to address these concerns have often been criticised for not going far enough. In the next chapter, we tell the story of current biofuels, and lay out the issues which have occurred during their large-scale development using a set of case studies.

[128] The Renewables Obligation Order 2009 amended by The Renewables Obligation (Amendment) Order 2010.

[129] These priorities reflect the existing policies. Defra's UK Biomass Strategy proposed a different order (heat, combined heat and power generation, co-firing, dedicated biomass power plants and then biofuels, reflecting the hierarchy in cost of carbon saved through each measure), see Defra (2007) *UK biomass strategy*, available at: http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/RESOURCES/REF_LIB_RES/PUBLICATIONS/UKBIOMASSSTRATEGY.PDF, p7.

[130] For example, see: International Risk Governance Council (2008) *Risk governance guidelines for bioenergy policies*, available at: http://www.irgc.org/IMG/pdf/IRGC_PB_Bioenergy_WEB-2.pdf, pp29–33.

Chapter 2

How did we get here? The story of biofuels

Chapter 2 – How did we get here? The story of biofuels

Box 2.1: Overview

Biofuels make up only a small fraction of overall fuel consumption in most countries, with the exception of Brazil. However, owing to the powerful drivers discussed in the previous chapter and existing policy incentives such as biofuel targets, the percentage of biofuels in the fuel mix has recently increased and is expected to rise significantly over the next two decades. It is therefore necessary to ensure that future large-scale biofuels production does not lead to unforeseen detrimental consequences.

After a brief description of the production of biofuels that are already established, this chapter outlines three case studies which illustrate the experiences gained in the development of biofuels from different sources in different countries: bioethanol from corn in the US; bioethanol from sugar cane in Brazil; and biodiesel from palm oil in Malaysia.

These three case studies show vividly that there were powerful incentives for governments to support the introduction of the particular biofuel in their country. The potential promises of biofuels were seen to justify policy instruments, standards and subsidies that supported commercial biofuels production, and there is little doubt that in all three cases, biofuels can be seen as a successful example of policy-driven economic development.

However, experience to date has shown that the promise is more uncertain than was once thought and biofuels involve significant problems. These include: concerns over food security and food prices; the rights of farmers, farm workers and land holders, particularly for vulnerable populations; and a wide range of problems related to environmental protection. These problematic effects have had major political and social repercussions, with protests against biofuels as extreme as violence in the streets. In response to some of these challenges governments have begun to develop new policies, although it is too early to have evidence of their impact.

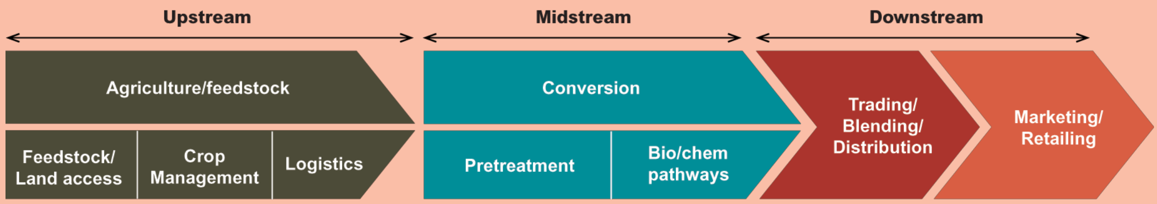
Introduction

2.1 Given the established policies to support biofuels, and the formidable forces behind those policies (described in Chapter 1), there is likely to be a reliance on current biofuels for the foreseeable future. Providers and suppliers striving to fulfil mandatory targets for renewable fuels will use the technological pathways that are best established and that can be scaled up quickly without requiring a great deal of additional research and investment. With very few exceptions, such scaling up of production is currently possible only with biofuels made from food crops. A transition to new biofuels will depend on future discoveries from scientific research and the effectiveness of policies to promote their development (discussed in Chapters 3 and 5). To respond to the challenges involved in evaluating *all* biofuels, it is important to understand the experience gained in the development of biofuels to date. Chapter 1 described the reasons why biofuels were seen as an attractive alternative to fossil fuels, and how worries over energy security, climate change and economic development continue to promote their development. This chapter provides information on the current production and use of biofuels and employs three examples to demonstrate the problems which became apparent once they were produced on a commercial scale – leading thus to the quest for better approaches to biofuels production.

Characteristics and production of biofuels

2.2 The diagram in Box 2.2 summarises the main practical steps that are involved in the three stages of the biofuels production chain. Upstream, a sufficient amount of biomass feedstock, i.e. the source material used for biofuels, is necessary and in most cases this involves issues of access to sufficient land. Crop management and logistics, such as transporting bulky biomass to the processing facility are also important stages in the upstream process and can present barriers to production. All stages of the midstream conversion process can involve significant practical obstacles, and there is potential for improvement (discussed in Chapter 3). Finally, blending, distributing and retailing the fuel, which are all important stages in the downstream part of production, depend on available infrastructure and the type of fuel.

Box 2.2: Biofuels production chain



2.3 Biodiesel is a convenient fuel with several advantages. It has been shown that biodiesel blends of 20 per cent[131] produce lower emissions (around 15 per cent less on average) of particulate matter, carbon monoxide, total hydrocarbons and other toxic compounds,[132] with potential advantages for air quality and public health.[133] Moreover, there are pragmatic advantages to biodiesel at several stages of the production chain. For example, the biodiesel production process of transesterification (see Box 2.3) is chemically rather simple. Biodiesel can also be delivered through existing distribution systems and – if produced to sufficiently high quality standards – can be used in cars without the need to alter vehicle fuel technology, an important feature to help achieve the goal of improved energy security (see Chapter 1). Some vehicles can even run on pure vegetable oil, avoiding the need for the transesterification process.

Box 2.3: Producing biofuels[134]

The production of biofuels involves three main stages.

Feedstock production (upstream)
In the case of established methods for biofuels production, this means growing and harvesting crops such as corn, soybean, wheat, sugar cane, sorghum, oilseed rape, oil palm, etc., using established agricultural practices. The resulting feedstocks then need to be stored (biomass is much bulkier per unit of energy than crude oil) and transported to the conversion facility.

Conversion of the feedstock (midstream)
Turning the feedstocks into biofuels involves pretreatment and processing. Biodiesel is made from plant oils or fats using the process of transesterification. The chemical name of biodiesel is fatty acid methyl (or ethyl) ester (FAME). The plant oils are mixed with sodium hydroxide and methanol (or ethanol) and the resulting chemical reaction produces FAME and glycerol (which can be used for other purposes). Bioethanol is made using microorganisms such as yeasts, and enzymes. Enzyme digestion releases sugars from starches derived from crops. Bioethanol is then produced by fermenting the sugars using yeast and removing water through distillation and dehydration. Biobutanol – a biofuel with higher energy content than bioethanol – can be produced in a similar fashion from similar feedstocks: rather than using yeast, the fermentation step is typically carried out by the bacterium *Clostridium acetobutylicum*.

Blending, distributing and selling the fuel end product (downstream)
Finally, biofuels need to be blended with petrol (with the exception of high-quality biodiesel) and transported so they can be sold at biofuel pumps. The distribution of biofuels often requires new infrastructure.

2.4 In contrast to biodiesel, bioethanol can only be used as a supplement in a fuel blend, with a typical 'blend wall' at 10 per cent bioethanol. This is in part due to the fact that ethanol absorbs water from the atmosphere and so cannot be used unmixed in current infrastructure. Replacing a higher percentage of petrol with ethanol, for example blending 15 per cent of petrol with 85 per cent of ethanol (E85 blend) requires cars with altered vehicle technology. In 2008, more

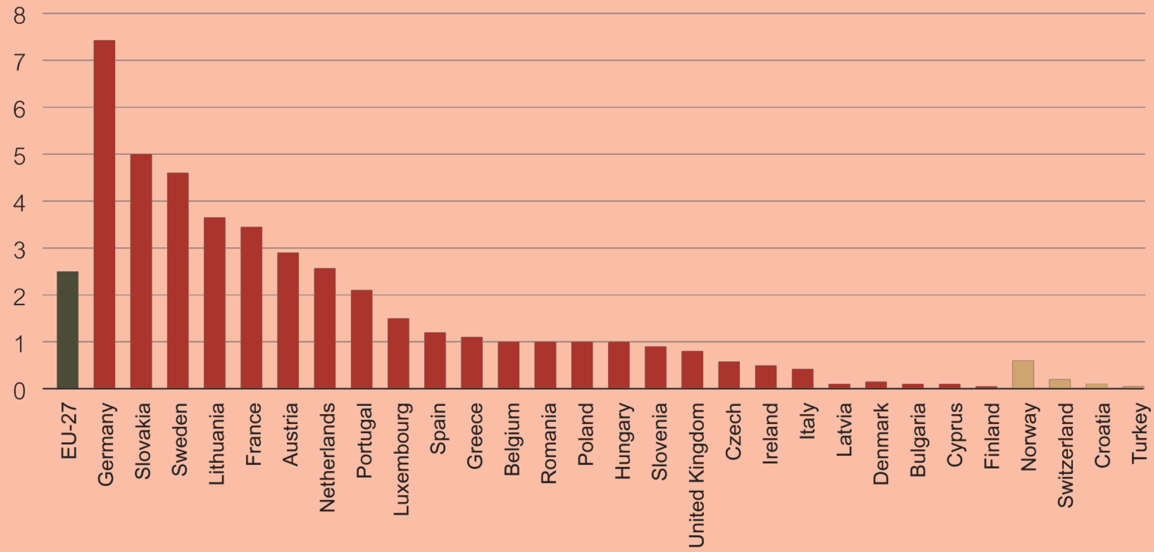
[131] That is, blends of 80 per cent petroleum diesel and 20 per cent biodiesel.
[132] McCormick RL (2007) The impact of biodiesel on pollutant emissions and public health *Inhalation Toxicology* **19**: 1033–9.
[133] This is an area of ongoing investigation. For example, it has been shown that in an animal exposure study, biodiesel exhaust has effects similar to that of conventional diesel. Meanwhile, some studies have found no difference between the fuels in terms of particulate matter causing mutations, whereas one study has shown that biodiesel causes fewer mutations owing to its lower emissions of these; see: McCormick (2007) The impact of biodiesel on pollutant emissions and public health *Inhalation Toxicology* **19**: 1033–9.
[134] Here, we describe the principles of biofuels production mainly with regard to the so-called 'first generation' biofuels made from food crops. Newer developments are detailed in the following chapter.

than 82 per cent of cars registered in Brazil in that year were flexible fuel vehicles[135] (2,33 million in 2008),[136] there were 8 million flexible fuel vehicles on the road in the US,[137] and over 215,000 on the road as of 2011 in Sweden.[138] At the end of 2009, there were only 604 petrol/alcohol vehicles on the road in the UK.[139] Both bioethanol and biodiesel have lower energy densities than their fossil fuel equivalents, so motorists will be able to drive fewer kilometres on a litre of these biofuels compared with a litre of conventional fuel. This affects retailing and is one reason why there is interest in developing biobutanol which has an energy density closer to that of petrol.

Current use of biofuels

2.5 Biofuels make up only a small fraction of overall fuel consumption in most countries, with the exception of Brazil. In 2007, the European average was approximately 2.5 per cent of overall transport fuel consumption, but with a large disparity between countries (see Box 2.4). Germany was in a very clearly leading position at over 7 per cent while the UK was below 1 per cent.

Box 2.4: Percentage of biofuels in total transport fuel consumption in Europe, 2007[140]



Data for Estonia and Malta not available.

Chart adapted from Eurostat.

2.6 Following the implementation of policy incentives as described in Chapter 1, the percentage of biofuels in the fuel mix has been growing, and is expected to continue to do so. In 2007, the International Energy Agency projected that by 2030 biofuels will account globally for seven percent of road transport fuel use.[141] And indeed, current developments support this prediction: for example, between 1998 and 2009, the production of biodiesel in the European Union

[135] A flexible fuel vehicle (FFV) is one that can operate on petrol, ethanol blends (such as E85) or a mixture of the two.
[136] ANFAVEA - Associação Nacional dos Fabricantes de Veículos Automotores (Brasil) (2009) *Brazilian Automotive Industry Yearbook, Vehicles – production, domestic sales, and exports*, available at: http://www.anfavea.com.br/anuario2009/capitulo2a.pdf, p70 and p73.
[137] National Renewable Energy Laboratory US Department of Energy (2011) *Alternative and advanced vehicles*, available at: http://www.eere.energy.gov/afdc/vehicles/flexible_fuel.html.
[138] BioAlcohol Fuel Foundation BAFF (Sweden) (2010) *Bought flexifuel vehicles – total per year*, available at: http://www.baff.info/english/.
[139] Personal communications, Robert Kennedy, The Society of Motor Manufacturers and Traders Limited.
[140] Eurostat (2010) *Share of biofuels in total fuel consumption of transport, 2007*, available at: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Share_of_biofuels_in_total_fuel_consumption_of_transport,_2007_%281%29_%28%25%29.PNG&filetimestamp=20100504144213.
[141] International Energy Agency (2007) *Renewables in global energy supply: an IEA fact sheet*, available at: http://www.iea.org/papers/2006/renewable_factsheet.pdf, p15.

increased more than ten-fold (see Box 2.5) – and this despite the fact that production is currently well below capacity.[142]

Box 2.5: EU Member States' biodiesel production ('000 tonnes)[143]

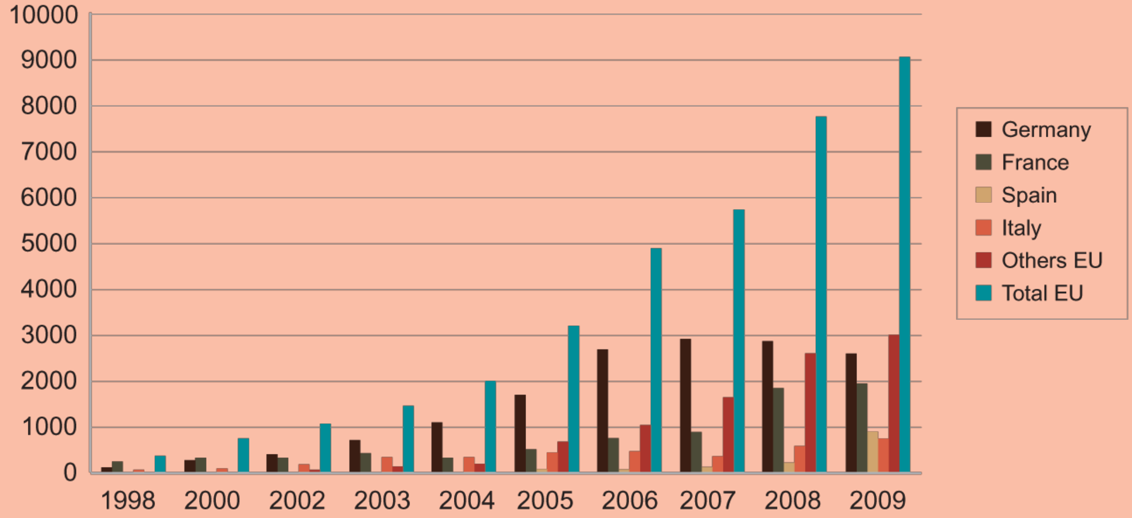


Chart adapted from European Biodiesel Board.

2.7 During 2008–2009, 2.7 per cent of UK road transport fuel was biofuel; 1,284 million litres of biofuel were supplied[144] – an increase on previous years. The upward trend continues: during 2009–2010, 1,568 million litres of biofuel were supplied, comprising 3.33 per cent of the UK's road transport fuel. This exceeded the Government's target of 3.25 per cent.[145] Biodiesel accounted for 71 per cent of biofuel supplied, with the most widely reported source of biodiesel being soybean from Argentina.[146] Bioethanol comprised 29 per cent of biofuel, mostly from Brazilian sugar cane.[147] Almost 200,000 kilograms of biogas were produced from municipal solid waste and then used as biofuel.[148] In Brazil in 2008–2009, almost 28 billion litres of bioethanol were produced from sugar cane.[149] Biodiesel production in Brazil, while developing, is relatively marginal. In the US, the minimum volume for renewable fuel was set at about 8 per cent in 2011 (where the percentage represents the ratio of renewable fuel volume to petrol and diesel volume).[150]

142 For example, in 2009 the European biodiesel production capacity was almost 21 million tonnes; however, only an estimated 9 million tonnes was produced; see: European Biodiesel Board (22 July 2010) *2009–2010: EU biodiesel industry restrained growth in challenging times*, available at: http://www.ebb-eu.org/EBBpressreleases/EBB%20press%20release%202009%20prod%202010_capacity%20FINAL.pdf, pp1 and 4.
143 European Biodiesel Board (2010) *The EU biodiesel industry*, available at: http://www.ebb-eu.org/stats.php.
144 Renewable Fuels Agency (2010) *Year one of the RTFO: Renewable Fuels Agency report on the Renewable Transport Fuel Obligation 2008/09*, available at: http://www.renewablefuelsagency.gov.uk/sites/renewablefuelsagency.gov.uk/files/_documents/year_one_of_the_rtfo_a4.pdf, p16. An Olympic-size swimming pool is a minimum of 2.5 million litres.
145 Renewable Fuels Agency (2011) *Year two of the RTFO*, available at: http://www.renewablefuelsagency.gov.uk/sites/rfa/files/Year_Two_RTFO_v2.pdf, p16.
146 Renewable Fuels Agency (2011) *Verified RFA quarterly report 8: 15 April 2009 – 14 April 2010*, available at: http://www.renewablefuelsagency.gov.uk/sites/rfa/files/24_RFA_verified_report_RTFO_year_two_v1.0.0_0.pdf, p2.
147 Ibid., p2.
148 Ibid., p21.
149 UNICA Sugar Cane Industry Association (2011) *Quotes and stats: ethanol production – Brazil*, available at: http://www.unica.com.br/downloads/estatisticas/eng/BRAZILIAN%20ETHANOL%20PRODUCTION.xls.
150 US Environmental Protection Agency (2010) *EPA finalizes 2011 Renewable Fuel Standards*, available at: http://www.epa.gov/otaq/fuels/renewablefuels/420f10056.pdf, p3.

Case studies

2.8 The following three case studies illustrate the experiences gained in the development of now commercially established biofuels from different feedstocks in different countries: bioethanol from corn in the US, bioethanol from sugar cane in Brazil, and biodiesel from palm oil in Malaysia. These particular case studies have been included for illustrative purposes and they are neither intended to represent all biofuels production nor all the issues associated with current biofuels. Indeed, we do not attempt to comment on or decide some of the contentious elements in each case study – a significant literature already exists on these topics and we could add little new insight. However, these case studies, which include the two biggest producers of biofuels in the world (the US and Brazil), vividly demonstrate some of the important issues that have emerged from large-scale production of biofuels. They thus provide us with important material for the ethical analysis of biofuels, which we undertake in the later chapters of this report. Moreover, information on the policy background helps to understand which of the drivers described in Chapter 1 were most relevant in each case study, and whether expectations were fulfilled. This lays some groundwork for our policy recommendations in Chapter 5.

Case study I: Bioethanol from corn in the US

Policy background

2.9 The US is the world's largest bioethanol producer: in 2009, an estimated almost 40 billion litres of ethanol were produced.[151] In the US, bioethanol is mainly derived from corn. A very small fraction of bioethanol is produced from sorghum.

2.10 The worry over energy security contributed significantly to the expansion of biofuels development in the US, in particular following the oil embargo by the Organisation of Petroleum Exporting Countries in 1973–1974. To reduce dependence on foreign sources of oil, a subsidy was introduced for the use of 'gasohol', a mixture of petrol and ethanol.[152] The subsidy did not at the time lead to a significant expansion of the ethanol industry as the price of oil dropped in the 1980s, making it difficult for the ethanol industry to compete even with the subsidy. However, in the 1990s, the subsidy once again became an incentive for US bioethanol production when the price of oil and oil imports rose. The incentive for bioethanol production has become more compelling as the price of oil has continued to rise. However, an even more important economic incentive for rapid expansion was the phasing out of methyl *tert*-butyl ether (MTBE) in the mid-1990s. MTBE was used as an oxygenate additive to petrol in order to raise the octane number, but it was found to be toxic and a powerful environmental pollutant. Declining use of MTBE created a demand for an oxygenate at an attractive price and led to a stampede among farmers groups who were interested in moving up the value chain. Finally, as mentioned before, agricultural overproduction rendered the conversion of food crops into biofuels an attractive prospect to farmers. Most of the corn bioethanol plants today are owned by groups of farmers who made the decision to finance and operate corn bioethanol plants entirely based on economic calculus.

2.11 Domestic legislation and policy have moreover in recent years created a favourable environment for the US corn-based bioethanol industry. A framework including legislation, mandates and other policies that support production, distribution and consumption of biofuels, including bioethanol specifically, exists at both federal and state levels (see Box 2.6).

[151] Renewable Fuels Association (2010) *Climate of opportunity: 2010 ethanol industry outlook*, available at: http://ethanolrfa.org/page/-/objects/pdf/outlook/RFAoutlook2010_fin.pdf?nocdn=1, p6.
[152] Tyner WE (2008) The US ethanol and biofuels boom: its origins, current status, and future prospects *BioScience* **58**: 646–53.

Box 2.6: Biofuels policy framework in the US

Under the Clean Air Act Amendments of 1990, the US Government requires the use of oxygenated gasoline (petrol) in areas with unhealthy levels of air pollution,[153] given that oxygenated gasoline burns with fewer harmful exhaust fumes than conventional gasoline. In one of the two associated programmes, bioethanol is the primary ingredient for oxygenation.[154]

The Energy Policy Act (EPAct) of 2005 established the Renewable Fuel Program.[155] This set the first renewable fuel volume mandate for fuel sold in the US, requiring that 7.5 billion US gallons (approximately 28 billion litres) of renewable fuel be blended with gasoline by 2012. The Energy Independence and Security Act (EISA) of 2007 later established the Renewable Fuel Standard (RFS) program, mandating that renewable fuels must account for 36 billion gallons (approximately 136 billion litres) of US transport fuel by 2022;[156] these numbers represent almost a nine-fold increase from the amount of bioethanol produced in the US in 2005.[157] Whereas other legislation – both domestic and European – has set minimum *proportions* for biofuels use in terms of total transport fuel used, US legislation has established standards for *absolute* biofuels use. EISA, while focusing on US energy security, also had environmental goals in that it required the US Environmental Protection Agency (EPA) to ensure that any renewable fuel, produced from facilities built after the enactment of EISA, produced fewer greenhouse gas (GHG) emissions than the petroleum fuel it replaced.[158] In February 2010, the EPA finalised its revision of the regulations for the RFS program. This established new specific annual volumes for renewable fuel to be used for transport.[159] It also included new definitions and criteria for both renewable fuels and the feedstocks used to produce them, including new GHG emissions savings thresholds as determined by life cycle assessment. The regulations for the RFS program apply to domestic and foreign producers and importers of renewable fuel used in the US. In addition, a whole suite of further policies are in place to promote bioethanol production.[160]

The US domestic bioethanol market has also been protected by policy. There is a 54 cents per gallon tariff on imported bioethanol, criticised by some as "[serving] largely to keep low-cost Brazilian ethanol from sugar cane out of the [US]".[161] Indeed, imports of bioethanol into the US have been recorded as being low (below 0.6 billion litres annually).[162]

Finally, individual states have implemented legislation that impacts on bioethanol production. For example, in California the Low Carbon Fuel Standard program has been enacted, which calls for a 10 per cent reduction in the carbon intensity of California's transportation fuels by 2020.[163]

To meet this policy-driven demand, by January 2010 there were an estimated 189 biorefineries in the US with a collective operating production capacity of approximately 45 billion litres of bioethanol a year.[164] As of November 2010, there were 204 operating bioethanol biorefineries with a total production capacity of approximately 52 billion litres.[165]

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153 sec 218 Clean Air Act Amendments of 1990.
154 US Environmental Protection Agency (2008) *Methyl tertiary butyl ether (MTBE)*, available at: http://www.epa.gov/mtbe/gas.htm.
155 sec 1501 Energy Policy Act of 2005.
156 s202 Energy Independence and Security Act of 2007.
157 US Energy Information Administration (2007) *Biofuels in the U.S. transportation sector*, available at: http://www.eia.doe.gov/oiaf/analysispaper/biomass.html.
158 s202 Energy Independence and Security Act of 2007.
159 US Environmental Protection Agency (2010) *EPA finalizes regulations for the national Renewable Fuel Standard program for 2010 and beyond*, available at: http://www.epa.gov/oms/renewablefuels/420f10007.pdf.
160 For example, the Volumetric Ethanol Excise Tax Credit (VEETC) was created under the American Jobs Creation Act 2004. The VEETC effectively subsidises the production of bioethanol in the US by crediting blenders who mix ethanol into gasoline with 51 cents per pure gallon of ethanol blended. Small ethanol producers with production capacity up to 60 million gallons are also supported: following the EPAct of 2005, they are credited with 10 cents per gallon as a production income tax credit. These credits were extended by the US Congress in December 2010 for a further year. In addition, there are policies to promote the use of bioethanol in transport, including the requirement under the EPAct of 2005 that the federal government fleet of dual-fuelled vehicles operate on alternative fuels.
161 Runge CF (2007) Biofuel: corn isn't the king of this growing domain *Nature* **450**: 478. In December 2010, the US Congress extended this tariff for a further year.
162 Oosterveer P and Mol APJ (2010) Biofuels, trade and sustainability: a review of perspectives for developing countries *Biofuels, Bioproducts and Biorefining* **4**: 66–76.
163 California Environmental Protection Agency Air Resources Board (2010) *Low Carbon Fuel Standard program*, available at: http://www.arb.ca.gov/fuels/lcfs/lcfs-background.htm.
164 Renewable Fuels Association (2010) *Climate of opportunity: 2010 ethanol industry outlook*, available at: http://ethanolrfa.org/page/-/objects/pdf/outlook/RFAoutlook2010_fin.pdf?nocdn=1, p3.
165 US Department of Energy (2011) *Biorefineries*, available at: http://cta.ornl.gov/bedb/biorefineries/Biorefineries_Overview.shtml. For the most up to date figures, see: Renewable Fuels Association (2011) *Biorefinery locations*, available at: http://www.ethanolrfa.org/bio-refinery-locations/.

Controversies over food security

2.12 Production of corn bioethanol in the US was blamed for causing increases in the price of corn and other grains and foods by increasing competition for finite vital resources. The 'tortilla riots' in Mexico during late 2006 and early 2007, widely publicised in the media, are one example. It has been reported that these were triggered when yellow corn – which had typically been imported from the US for use as animal feed – increased in price. Mexicans began to use white corn, a grain that is traditionally used to make tortilla, as animal feed instead, and thus the price of white corn and tortilla soared.[166] Tortilla is a staple food for the poor. When prices rose, street demonstrations occurred with thousands marching down the street and the Mexican Government eventually had to intervene to subsidise the sale of corn for tortillas.

2.13 These consequences of (not only) US biofuels production for food security are the subject of fierce debate (see Box 2.7). Several recent reports by advocacy organisations have accused large-scale biofuels production of driving up food prices or threatening food security by other means, using the strongest language of human tragedy and misery.[167] In addition, the *Gallagher Review*, an independent review prepared for the UK Government of the indirect effects of current biofuels production, found that increasing demand for biofuels contributed to rising food prices that harm the poor.[168] However, the review noted that the scale of effects on the prices of commodities was both complex and uncertain to model. Indeed, while there is general agreement that biofuels production did contribute to high food prices, there is little consensus as to the extent of its impact.

Box 2.7: Biofuels and food security: controversies

On the Mexican tortilla riots

"There is another problem with relying on a food-based biofuel, such as corn ethanol, as the poor of Mexico can attest. In recent months, soaring corn prices, sparked by demand from ethanol plants, have doubled the price of tortillas, a staple food. Tens of thousands of Mexico City's poor recently protested this 'ethanol tax' in the streets."[169]

"…the allegation that the increase in corn prices in the US led to food price increases overall and specific corn shortages in Mexico was exaggerated. It seems that [an] increase in oil/gasoline prices and related increases in natural gas/fertilizer prices contributed to the increase in prices and the supply/demand/price consequences we observed."[170]

On biofuels and food security

President Luiz Inácio Lula da Silva, Brazilian President: "Biofuels aren't the villain that threatens food security."[171]

Jean Ziegler, United Nations Special Rapporteur on the Right to Food: "[Biofuels are] a crime against humanity".[172]

2.14 For example, a research paper in 2008 found that from June 2002 until June 2008 "biofuels and the related consequences of low grain stocks, large land use shifts, speculative activity and export bans" accounted for approximately 70–75 per cent of the increase in food prices during

[166] For more details, see: Westhoff P (2010) *The economics of food: how feeding and fueling the planet affects food prices* (New Jersey: FT Press), pp17–9. Westhoff also notes that the increase in yellow corn prices may have provided an incentive for at least some Mexican farmers to grow yellow corn rather than white corn. This too would have affected the availability of white corn for tortilla.

[167] For example, see: ActionAid (2010) *Meals per gallon: the impact of industrial biofuels on people and hunger*, available at: http://www.actionaid.org.uk/doc_lib/meals_per_gallon_final.pdf; Friends of the Earth Europe (2010) *Africa: up for grabs: the scale and impact of land grabbing for agrofuels*, available at: http://www.foeeurope.org/agrofuels/FoEE_Africa_up_for_grabs_2010.pdf, p27; Christian Aid (2008) *Fighting food shortages: hungry for change*, available at: http://www.christianaid.org.uk/Images/food_report_2008.pdf, pp3–4.

[168] Renewable Fuels Agency (2008) *The Gallagher Review of the indirect effects of biofuels production*, available at: http://www.renewablefuelsagency.gov.uk/sites/renewablefuelsagency.gov.uk/files/_documents/Report_of_the_Gallagher_review.pdf, p9.

[169] David Tilman, ecologist at the University of Minnesota, and Jason Hill, research associate in the Department of Applied Economics at the University of Minnesota, writing in: The Washington Post (25 Mar 2007) *Corn can't solve our problem*, available at: http://www.washingtonpost.com/wp-dyn/content/article/2007/03/23/AR2007032301625.html.

[170] Advanced Biofuels USA, responding to the Working Party's consultation.

[171] President Lula speaking at a conference of the Food and Agriculture Organization of the United Nations in Brazil, 2008: BBC News (17 Apr 2008): *Brazil president defends biofuels*, available at: http://news.bbc.co.uk/1/hi/sci/tech/7351766.stm.

[172] Mr Ziegler speaking at the UN headquarters in New York City, 2007: BBC News (27 Oct 2007) *Biofuels 'crime against humanity'*, available at: http://news.bbc.co.uk/1/hi/world/americas/7065061.stm.

that period, and that the combination of higher energy prices (and subsequent increases in fertiliser and transport costs) and a weak dollar explained 25–30 per cent of the total price rise.[173] Overall, the most important factor was seen to be the large increase in biofuels production in the US and the EU.[174] However, this conclusion was subsequently rebutted by a paper for the World Bank in 2010.[175] It is now apparent from this and many other reports, for example from the UK Government,[176] that the effect of biofuels on food prices was smaller than first believed, and that other factors, such as high energy prices and the weak dollar, were more significant.

2.15 In sum, biofuels, and US corn bioethanol in particular, appear to be one contributing factor to changing food commodity prices, which can affect vulnerable countries and populations. However, there are several other factors which also play important roles in destabilising food prices. Blaming food price spikes on biofuels production alone – a frequent argument in our public consultation – would appear to be one-sided.

Environmental issues

2.16 US production of corn bioethanol has given rise to controversy over its impacts on the environment, including its greenhouse gas (GHG) emissions in comparison with the fossil fuels it replaces and deleterious effects on air quality, soil, health and water resources.

2.17 *GHG emissions from indirect land use change*: Research has raised questions over whether corn bioethanol achieves GHG emissions savings compared with fossil fuel usage.[177] This is mainly because of the release of carbon from land, newly cultivated as an often indirect consequence of increased corn production for ethanol. A well-known yet highly contested study by Searchinger *et al.* (2008)[178] estimated the extent of potential land use change in response to a possible increase in US corn ethanol production of 56 billion litres above projected levels for 2016.[179] This study made the assumption that, as more US cropland is used to support bioethanol production, and given that the US exports corn to countries such as India, China and Brazil, these countries would generally replace their reduced imports of US corn by cultivating more land, including forest and grassland (so-called indirect land use change (iLUC), see Box 2.8). This would release much of the carbon stored in soils and plants through either combustion or decomposition. The analysis found that production of corn bioethanol increases GHG emissions for 167 years, after which point the GHG emissions savings from use of corn bioethanol finally equalises the carbon emissions from land use change. Over the first 30 years, GHG emissions from corn bioethanol are projected to be nearly double those from petrol per kilometre driven. However, the issue of land use change is highly controversial (see Box 2.9), as

173 Mitchell D (2008) *A note on rising food prices*, available at: http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2008/07/28/000020439_20080728103002/Rendered/PDF/WP4682.pdf, pp16–7.
174 Ibid.
175 Baffes J and Haniotis T (2010) *Placing the 2006/08 commodity price boom into perspective*, available at: http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2010/07/21/000158349_20100721110120/Rendered/PDF/WPS5371.pdf. This paper concluded that the dominant influence on food markets was likely to be the strong link between energy and non-energy commodity prices. The paper also argued that the effect of biofuels was not as large as originally thought; instead the price spike for 2007/08 may have been caused in part by financial investors using commodities.
176 HM Government (2010) *The 2007/08 agricultural price spikes: causes and policy implications*, available at: http://www.defra.gov.uk/foodfarm/food/pdf/ag-price100105.pdf, p114.
177 While many studies concentrate specifically on GHG emissions, others have taken a broader perspective. For example, for a study that incorporates an economic cost–benefit analysis, see: de Gorter H (2010) Does US corn-ethanol really reduce emissions by 21%? Lessons for Europe *Biofuels* **1**: 671–3.
178 Searchinger T, Heimlich R, Houghton RA *et al.* (2008) Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change *Science* **319**: 1238–40. For a list of limitations identified in the study, see: Renewable Fuels Agency (2008) *The Gallagher Review of the indirect effects of biofuels production*, available at: http://www.renewablefuelsagency.gov.uk/sites/renewablefuelsagency.gov.uk/files/_documents/Report_of_the_Gallagher_review.pdf, p47.
179 Searchinger T, Heimlich R, Houghton RA *et al.* (2008) Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change *Science* **319**: 1238–40.

is any calculation of iLUC (see Box 2.8). For example, a subsequent study estimated that the associated GHG release for corn bioethanol production in the US was roughly a quarter of Searchinger's 30 year estimate.[180] This study differed from Searchinger's in that not only did it factor in market-mediated responses to increased biofuels production in the US, but it also accounted for the use of by-products.

Box 2.8: Life cycle assessment of biofuels: nitrous oxide emissions, dLUC and iLUC

Life cycle assessment (LCA) of biofuels considers the environmental and resource impacts associated with: growing the crop (including soil cultivation, fertiliser production, irrigation and harvesting); transporting the biofuels feedstock; converting the feedstock to biofuels (including extraction of sugars/oils, processing and refining); and transporting biofuels to the point of use. Although LCA can also include assessment of specific resources, such as water or energy, that are used throughout the life cycle of a biofuel, most applications currently focus on GHG emissions. Recently, there has been controversy around several areas of scientific uncertainty and debate in LCA, which are important because of the potential size of their contributions to total GHG emissions. Only the basic aspects of these particular issues are introduced here while consideration of how to resolve them is addressed elsewhere (in Chapter 5).

Nitrous oxide emissions from soils: Soil nitrous oxide emissions arise mainly from the application of nitrogen fertilisers to crops. Although the mechanisms for nitrous oxide formation in soils are well understood, the relationship between the rate of nitrogen-based fertiliser application and the soil nitrous oxide emissions depends on a variety of factors that can be difficult to determine. In themselves, soil nitrous oxide emissions can be relatively small but their significance is magnified by the fact that, on an equal weight basis, nitrous oxide is approximately 300 times more powerful than carbon dioxide in terms of the greenhouse effect.[181]

Direct land use change: Direct land use change (dLUC) involves converting land from a previous use (mainly grassland, forest or woodland, peatland and wetland) to the cultivation of biofuels crops. In all such cases, significant carbon stocks can be destroyed and released as carbon dioxide emissions. The connection between these GHG emissions and biofuels production is direct, as both the previous use of the land and its specific conversion to biofuels crop cultivation should be known. Hence, it would seem simple to ensure that estimated additional GHG emissions are attributed to the biofuels produced. However, this requires that we specify the number of years of crop production to which the GHG emissions from dLUC are attributed and this can involve a nominal time horizon which is not justified explicitly.

Indirect land use change: Determining the effects of iLUC is more complicated than for dLUC. Growing biofuels crops on existing agricultural land may result in displacing existing cultivation of food and other crops elsewhere. This displacement, if it involves the destruction of carbon stocks in grassland, forest or woodland, peatland or wetland, will result in the release of substantial carbon dioxide emissions. From an extreme perspective, all these GHG emissions are attributed to the biofuels crop which caused the iLUC. Again, a fixed quantity of initial GHG emissions is attributed to a cumulative amount of biofuels produced over a nominal time horizon. However, the contentious issue is to determine which biofuels crop causes the displacement and what subsequent iLUC actually occurs. There are many factors which cause land use change and these include: increasing requirements for food (e.g. due to a growing world population); changing dietary preferences (e.g. in response to increasing wealth and switches to food products that use proportionally more land); expanding use of land for non-food production (e.g. materials and chemicals as well as biofuels); degradation of agricultural land (i.e. where it is no longer productive); and continued urbanisation (this causes direct and indirect degradation and loss of land for cultivation). Conversely, improvements in crops and agricultural practices can increase yield and reduce pressure on iLUC. Additionally, the inclusion of certain by-products, such as animal feeds, into the evaluation of GHG emissions for biofuels can reduce the impact of iLUC.[182] It is currently extremely difficult to disentangle such factors and, hence, there is much uncertainty over the allocation of GHG emissions from iLUC to the production of specific biofuels. While recent studies have attempted to quantify the potentially significant magnitude of iLUC associated with large-scale biofuels production,[183] considerable uncertainties with current land use change modelling have prevented the official resolution of this issue.[184]

These uncertainties surrounding LCA are reflected in the results of analyses of the impact of current biofuels, which differ significantly. Some recent LCAs have shown that biofuels can have marginal or even negative GHG emissions savings

180 Hertel TW, Golub AA, Jones AD *et al.* (2010) Effects of US maize ethanol on global land use and greenhouse gas emissions: estimating market-mediated responses *BioScience* **60**: 223–31.

181 The potency of GHGs is measured by their global warming potential (GWP) relative to CO_2. According to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, GWPs over a 100 year time horizon are such that one kilogram of methane is equivalent to 25 kilograms of carbon dioxide, and one kilogram of nitrous oxide is equivalent to 298 kilograms of carbon dioxide.

182 See, for example: Taheripour F, Hertel TW, Tyner WE, Beckman JF and Birur DK (2010) Biofuels and their by-products: global economic and environmental implications *Biomass & Bioenergy* **34**: 278–89; Cockerill S (25 Nov 2010) *Biorefining wheat to produce green food and fuel*, presented at: 4th ICIS Bioresources Summit, Gateshead, UK.

183 See, for example: Institute for European Environmental Policy (2010) *Anticipated indirect land use change associated with expanded use of biofuels and bioliquids in the EU – an analysis of the National Renewable Energy Action Plans*, available at: http://www.ieeplondon.org.uk/publications/pdfs/2010/iluc_analysis.pdf.

184 European Commission (2010) *Report from the Commission on indirect land-use change related to biofuels and bioliquids*, available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0811:FIN:EN:PDF, p14.

compared with fossil fuels. For example, in the *Science* study by Searchinger *et al.* mentioned above, the authors find significantly negative GHG emissions savings for US ethanol made from corn due mainly to the effect of iLUC.[185] Others, using different models for determining land use change, derive more favourable numbers for overall GHG emissions from biofuels production, including for some types of corn ethanol production.[186] The issue is further complicated by the fact that co-products from biofuels production can affect – indeed in some cases improve – LCA and iLUC outputs.[187]

Box 2.9: Land use change: controversy

On the existence of land use change

"Land use change is a big [myth] invented by [opponents of] biofuels. It simply has to be assured that the feedstock for biofuels is grown in a sustainable way. This is generally the case, only few exceptions exist. It is wrong to concentrate on the few bad exceptions (which of course are not tolerable and have to be avoided)."[188]

"This land use problem is not just a secondary effect — it was often just a footnote in prior papers…It is major. The comparison with fossil fuels is going to be adverse for virtually all biofuels on cropland."[189]

On the calculation of iLUC

"The scientific basis for indirect land use change is extremely weak…ILUC modelling and analysis is the wrong tool for assessing these issues. Rather, better land management is required…"[190]

"The fact that Indirect Land Use change is happening must be taken into account when calculating GHG emissions. However, it is impossible to quantify precisely."[191]

2.18 *Water implications*: A report by the US National Research Council reviewed the water implications of biofuels production in the US, using some data from a study by the Sandia National Laboratories. This study had estimated that the amount of water used by a corn ethanol plant is in the region of 4 gallons of water per gallon of ethanol produced.[192] In contrast, water used in petroleum refining is about 1.5 gallons per gallon of fuel produced.[193] The US National Research Council report additionally calculated that the amount of water required in growing the corn for biofuels is about 200 times greater than the amount needed for processing each gallon of ethanol.[194] It subsequently interpreted these data as showing that biorefineries generated local but intense water supply challenges, and that irrigated agriculture could generate problems for the wider region (depending on whether agriculture is rain-fed or not).[195]

2.19 With regard to water quality, the report considered fertiliser run-off and nutrient pollution, as well as pesticide use. Compared with other feedstocks such as soybean and mixed-species grasses, the greatest application rates of fertilisers and pesticides per acre were for corn.[196] It was noted that, all else being equal, the conversion of land from other crops or non-crop plants to corn would probably lead to much higher application rates of nitrogen. Thus, there was considerable potential for additional corn bioethanol production to increase the severity of nutrient pollution in waterways,[197] such as the Mississippi River system. Nutrient pollution here is already a major

[185] Searchinger T, Heimlich R, Houghton RA *et al.* (2008) Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change *Science* **319**: 1238–40.
[186] For example, see: US Environmental Protection Agency (2010) *EPA finalizes regulations for the national Renewable Fuel Standard program for 2010 and beyond*, available at: http://www.epa.gov/oms/renewablefuels/420f10007.pdf, p5.
[187] Taheripour F, Hertel TW, Tyner WE, Beckman JF and Birur DK (2010) Biofuels and their by-products: global economic and environmental implications *Biomass & Bioenergy* **34**: 278–89.
[188] Anonymous respondent, responding to the Working Party's consultation.
[189] Dr Timothy Searchinger, Princeton University, quoted in The New York Times (8 Feb 2008) *Biofuels deemed a greenhouse threat*, available at: http://www.nytimes.com/2008/02/08/science/earth/08wbiofuels.html?pagewanted=1&_r=2.
[190] BP, responding to the Working Party's consultation.
[191] Food Not Fuel, responding to the Working Party's consultation.
[192] Sandia National Laboratories (2007) *Overview of energy-water interdependencies and the emerging energy demands on water resources* (Los Alamos, New Mexico: Sandia National Laboratories), p13.
[193] Ibid, p8.
[194] Committee on Water Implications of Biofuels Production in the United States, National Research Council (2008) *Water implications of biofuels production in the United States*, available at: http://books.nap.edu/openbook.php?record_id=12039&page=51, p51.
[195] Ibid.
[196] Ibid, p27.
[197] Ibid, p31.

cause of the "dead zone" in the Gulf of Mexico – a region where many forms of marine life cannot survive owing to low oxygen levels. The report warned: "If projected future increases in use of corn for ethanol production do occur, the increase in harm to water quality could be considerable."[198] Sedimentation arising from soil erosion into water bodies was also investigated, as sediments can impair water quality and carry pollutants.

Case study II: Bioethanol from sugar cane in Brazil

Policy background

2.20 Bioethanol production from sugar cane in Brazil, one of the longest standing biofuels programmes, has been described as the most successful example of producing and using biofuels on a large scale.[199] Large-scale production started when the Brazilian Government began to promote bioethanol as a transport fuel in response to the energy crisis of the 1970s. In 1975, the Brazilian Government launched the national alcohol programme "PróÁlcool" (Programa Nacional do Álcool). The intention was to phase out fossil fuels and to replace them with ethanol made from sugar cane.[200] By the mid 1980s, around three quarters of Brazilian cars were manufactured with engines that could use ethanol.[201] Flexible fuel cars were introduced in Brazil in 2003, and by 2008 almost 70 per cent of all vehicles produced were flexible fuel.[202]

2.21 Brazil is the world's second largest producer of ethanol fuel after the US (some predict that it will overtake the US in the near future) and the world's largest exporter. In 2008, it produced an estimated 27 per cent of the world's total bioethanol for fuel.[203] Production processes in Brazil are being improved continuously and Brazilian scientists have published a number of academic papers outlining advances in bioethanol production, such as in the use of yeasts or enzymes during conversion or the use of by-products such as molasses for electricity generation. The FAPESP Program for Research on Bioenergy, BIOEN, was launched in 2008 with the aim of integrating Brazilian biofuels research.[204]

2.22 The Brazilian Government encouraged the development of ethanol in several ways. There were guaranteed purchases of ethanol by the state-owned oil company Petrobras. In addition, ethanol prices were both lower than and fixed relative to the price of petrol (ethanol sold for 64.5 per cent of the petrol price at the pump), and agro-industrial firms willing to produce ethanol were offered economic incentives in the form of low interest rates.[205] These initiatives made ethanol economically competitive to produce and attractive to consumers, and have been credited with much of the success of the PróÁlcool programme. It is interesting to note that at the time of the launch of PróÁlcool, concern over energy security and high crude oil prices was the dominant motivation, with economic development running second. There was virtually no interest in lowering GHG emissions, since climate change had only just begun to emerge as an issue of public concern. However, recently the GHG emissions savings that can be generated through the production and use of bioethanol have been discussed as an additional and important driver for Brazilian bioethanol production.

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198 Ibid, p35.
199 Matsuoka S, Ferro J and Arruda P (2009) The Brazilian experience of sugarcane ethanol industry *In Vitro Cellular & Developmental Biology* **45**: 372–81.
200 Ibid.
201 ANFAVEA - Associação Nacional dos Fabricantes de Veículos Automotores (Brasil) (2009) *Brazilian automotive industry yearbook: vehicles – production, domestic sales, and exports*, available at: http://www.anfavea.com.br/anuario2009/capitulo2a.pdf, p64.
202 Ibid.
203 Renewable Fuels Association (2008) *Ethanol industry statistics: 2008 world fuel ethanol production*, available at: http://www.ethanolrfa.org/pages/statistics#E.
204 BIOEN consists of five divisions which focus on: biomass research; ethanol technologies and processing; biorefineries and alcohol chemistry; engines; and social, environmental and economic impacts; see: BIOEN (2011) *FAPESP Bioenergy Program – BIOEN*, available at: http://bioenfapesp.org/index.php?option=com_content&view=article&id=170&Itemid=151&lang=en.
205 Goldemberg J (2008) The Brazilian biofuels industry *Biotechnology for Biofuels* **1**: 6–13.

2.23 The uptake rate of bioethanol in Brazil is unparalleled compared with anywhere else in the world. Bioethanol prices were competitive with gasoline based on international prices for oil in 2004,[206] though oil prices have since risen. Moreover, prices continue to benefit from certain tax exemptions.[207] Some have heralded Brazil as a successful example of an emerging economy using the development of alternative fuels for national economic development, with the added potential benefit of supporting climate change mitigation.

Potential environmental impacts

2.24 Brazilian bioethanol production has not gone unchallenged. For example, it has been claimed that production of ethanol from sugar cane generates GHG emissions savings of about 90 per cent.[208] However, following such estimates, the overall sustainability of bioethanol production from Brazilian sugar cane has been questioned, for example when iLUC or direct conversion of the Brazilian Cerrado are taken into account when estimating GHG emission savings.[209] On the other hand, ethanol made from sugar cane, such as ethanol from Brazil, complies with the EPA threshold for classification as an "advanced biofuel" (50 per cent GHG emission reduction).[210] However, as described above in Box 2.8, calculating GHG emissions remains controversial.

2.25 *Water use*: Concerns regarding water use of Brazilian sugar cane production and possible contamination of water by use of fertiliser, have been raised in the past. Sugar cane production is highly water intensive (using up to 4 litres of water per litre of ethanol produced).[211] A recent study[212] concluded that the amount of water used for ethanol production in Brazil has decreased and water pollution can be avoided, for example by giving up use of agrochemicals and replacing these with less toxic alternatives. However, Brazilian wastewater standards are not as strict as other comparable standards and it seems that some agrochemicals are allowed that are banned in the EU.[213]

2.26 *Deforestation*: There have also been criticisms surrounding the possibility that areas with high environmental value will be cleared for sugar cane production, such as the Pantanal or the Cerrado. These are areas of high biodiversity, and an expansion of agricultural production may destroy these rich habitats and their associated biodiversity.[214] Deforestation in the Cerrado and the Amazon increased rapidly during 2005–2007[215] and through modelling this has been linked – some say incorrectly – to an increased area of sugar cane plantation elsewhere in Brazil.[216]

[206] Ibid.

[207] Woodrow Wilson International Center for Scholars (2007) *The global dynamics of biofuels: potential supply and demand for ethanol and biodiesel in the coming decade*, available at: http://www.wilsoncenter.org/topics/pubs/Brazil_SR_e3.pdf, p6.

[208] European Commission (2007) *Biofuels progress report: report on the progress made in the use of biofuels and other renewable fuels in the Member States of the European Union*, available at: http://ec.europa.eu/energy/energy_policy/doc/07_biofuels_progress_report_en.pdf, p11.

[209] Lapola DM, Schaldach R, Alcamo J *et al.* (2010) Indirect land-use changes can overcome carbon savings from biofuels in Brazil *Proceedings of the National Academy of Sciences of the United States of America* **107**: 3388–93.

[210] US Environmental Protection Agency (2010) *EPA finalizes regulations for the national Renewable Fuel Standard program for 2010 and beyond*, available at: http://www.epa.gov/oms/renewablefuels/420f10007.pdf, p5.

[211] Sawyer D (2008) Climate change, biofuels and eco-social impacts in the Brazilian Amazon and Cerrado *Philosophical Transactions of the Royal Society B: Biological Sciences* **363**: 1747–52.

[212] Smeets E, Junginger M, Faaij A, et al. (2008) The sustainability of Brazilian ethanol: An assessment of the possibilities of certified production, *Biomass and Bioenergy* **32**: 781–813.

[213] Ibid.

[214] United Nations Environment Programme (2009) *Towards sustainable production and use of resources: asessing biofuels*, available at: http://www.unep.fr/scp/rpanel/pdf/assessing_biofuels_full_report.pdf, p69; Martinelli LA and Filoso S (2008) Expansion of sugarcane ethanol production in brazil: Environmental and social challenges *Ecological Applications* **18**: 885–98; Oxfam International (2008) *Another inconvenient truth*, available at: http://www.oxfam.org.uk/resources/policy/climate_change/downloads/bp114_inconvenient_truth.pdf; Sawyer D (2008) Climate change, biofuels and eco-social impacts in the Brazilian Amazon and Cerrado *Philosophical Transactions of the Royal Society B* **363**: 1747–52.

[215] Sawyer D (2008) Climate change, biofuels and eco-social impacts in the Brazilian Amazon and Cerrado *Philosophical Transactions of the Royal Society B* **363**: 1747–52.

[216] Lapola DM, Schaldach R, Alcamo J et al (2010) Indirect land-use changes can overcome carbon savings from biofuels in Brazil *Proceedings of the National Academy of Science* **107**: 3388–93.

Expansion of agriculture into areas of high biodiversity is neither inevitable nor necessarily due to increased biofuels production. However, rapid scaling up of production in response to increasing worldwide interest in biofuels may cause production to expand into valuable wildlife habitats. In a different example, rapid scaling up of soybean plantation for biodiesel production in Brazil has resulted in direct conversion of forest land in the Amazon into cropland. Biodiesel from this land has been accused of severe environmental effects.[217]

2.27 To avoid the destruction of valuable forest land and in response to international criticism, the Brazilian Government set up in September 2009 countrywide agro-ecological land use zoning, ZAE Cana, to restrict sugar cane growth in or near environmentally sensitive areas.[218] Today, around one per cent of Brazil's landmass, equivalent to 7.8 million hectares (one hectare is roughly the area of a sports field), is used for growing sugar cane (with great regional variation). ZAE Cana includes a set of mandatory environmental, economic, social, climate and soil restrictions, limiting future expansion of sugarcane to 7.5 per cent of the Brazilian territory. Under the criteria, 92.5 per cent of the country is not suitable for planting sugar cane. Projections from the Brazilian Ministry of Agriculture indicate that if Brazilian production doubled by 2017, not more than 1.7 per cent of the land would be used.[219]

2.28 *Field burning*: To facilitate harvesting, sugar cane fields are burned prior to the harvest. This is done to avoid harm to workers from snakes and sharp leaves, but has in the past led to soil contamination and air pollution.[220] A state law came into force which bans burning in sugar cane fields in flat and hilly areas by 2021 and 2031 respectively (agreements with industry exist to stop burning ahead of these targets by 2014 or 2017).[221] In the meantime, advances in fertilisers and mechanisation of farming systems have reduced the need for field burning.

Workers' rights

2.29 Brazil has been accused in the past of not tracking breaches of workers' rights;[222] in addition, there have been reports of contemporary slavery among sugar cane cutters in Brazil. For example, in 2007, Amnesty International highlighted the rescue of more than 2,000 workers from forced labour or conditions analogous to slavery.[223] Owing to a lack of rural jobs for unskilled workers, many of the freed workers will typically later return to the industry. Unhealthy working conditions and even deaths from overwork during sugar cane cutting have also been reported.[224] Sugar cane cutting is extremely demanding. In endeavouring to meet the higher productivity levels set by mechanised sugar cane cutting and to earn as much money as possible (the amount earned depends on the amount cut), sugar cane cutters are estimated to strike a machete up to 12,000 times a day.[225] Field research has revealed that the use of anti-

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[217] United Nations Environment Programme (2009) *Towards sustainable production and use of resources: asessing biofuels*, available at: http://www.unep.fr/scp/rpanel/pdf/assessing_biofuels_full_report.pdf, p63.

[218] Ministério da Agricultura, Pecuária e Abastecimento (2009) *Zonamento Agroecologico de Cana-de-Acucar*, English version available at: http://www.unica.com.br/downloads/sugarcane-agroecological-zoning.pdf.

[219] Ibid.

[220] Martinelli LA and Filoso S (2008) Expansion of sugarcane ethanol production in Brazil: environmental and social challenges *Ecological Applications* **18**: 885–98.

[221] Reuters (5 Sep 2008) *Brazil SP cane growers to ban burning by 2017*, available at: http://in.reuters.com/article/environmentNews/idINN0439664020080904.

[222] Martinelli LA and Filoso S (2008) Expansion of sugarcane ethanol production in Brazil: environmental and social challenges. *Ecological Applications* **18**: 885–98.

[223] Amnesty International (2008) *Brazil – Amnesty International report 2008*, available at: https://www.amnesty.org/en/region/brazil/report-2008#.

[224] Martinelli LA and Filoso S (2008) Expansion of sugarcane ethanol production in Brazil: environmental and social challenges. *Ecological Applications* **18**: 885–98; Sawyer D (2008) Climate change, biofuels and eco-social impacts in the Brazilian Amazon and Cerrado *Philosophical Transactions of the Royal Society B* **363**: 1747–52; Smeets E, Junginger M, Faaij A *et al.* (2008) The sustainability of Brazilian ethanol: An assessment of the possibilities of certified production *Biomass and Bioenergy* **32**: 781–813.

[225] Dr Ben Richardson, responding to the Working Party's consultation; Sawyer D (2008) Climate change, biofuels and eco-social impacts in the Brazilian Amazon and Cerrado *Philosophical Transactions of the Royal Society B* **363**: 1747–52.

inflammatory drugs and painkillers is prevalent among cane cutters.[226] In addition, it was reported that an investigation by the Brazilian Ministry of Labour into the death of a cane cutter found that he had worked a shift lasting 70 uninterrupted days.[227] There is also informal child labour and the number of child workers has been estimated at 3 per cent of the total employed in sugar cane ethanol production.[228] Enforcement of labour laws in Brazil is weak.[229]

2.30 With regard to wages, average wages in the São Paulo region, where production is mainly centred, are now higher than the Brazilian minimum wage, but may still not be sufficient to avoid poverty. Wages in other regions vary and may be even lower than the minimum wage.[230] Difficulties also exist in the method of payment. In sugar cane plantations a system of payment on production exists, in which – in contrast to other analogous forms – the workers do not know beforehand exactly how much they produce. The amount is only known after the work is done and following a measuring process that is kept secret from them. Such practice encourages overworking.[231] Cutters may also have to pay excessive fees for food, housing or return transport when they move to a sugar cane estate.[232] While the early bioethanol industry increased employment opportunities, employment numbers have since fallen owing to increasing mechanisation of harvesting.[233] According to the sugar cane processing union UNICA, around 34,000 net jobs are expected to be lost in São Paulo alone by 2020 (i.e. 114,000 jobs lost and 80,000 new jobs gained).[234] This general trend of job losses is expected to continue, although it is thought that manual cane cutting is unlikely to disappear in the short term (for example, it is expected that it will continue on hillier areas and as the low-risk option for harvest expansion).[235] Displacement of agricultural populations and the use of seasonal labour lead to physical and cultural disruption of multifunction family farms and traditional communities.[236]

2.31 On the other hand, the ethanol production sector maintains social and educational services such as schools and day care and nursery centres. More than 80 per cent of production facilities provide some health and pharmaceutical care, transportation, collective life insurance and meals.[237]

2.32 The Brazilian government has endeavoured to address the issue; it publishes a 'dirty list' of firms that have been cited for the use of slave labour.[238] Addition to this list means that companies lose access to official means of obtaining credit, for example as provided by Brazil's National Development Bank. However, difficulties remain with this approach in that it can take

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226 Dr Ben Richardson, responding to the Working Party's consultation; Alves F (2008) Work processes and damage to the health of sugar cane cutters *InterfacEHS – A Journal on Integrated Management of Occupational Health and the Environment* **3**: 1–22.
227 Ethical-Sugar (19 Jun 2007) *IUF – Tuesday 19 June 2007*, available at: http://www.sucre-ethique.org/Brazil-Cane-Cutters-Strike-in-Sao.html.
228 Smeets E, Junginger M, Faaij A *et al.* (2008) The sustainability of Brazilian ethanol: an assessment of the possibilities of certified production *Biomass and Bioenergy* **32**: 781–813.
229 Ibid.
230 Ibid.
231 Alves F (2008) Work processes and damage to the health of sugar cane cutters *INTERFACEHS – A Journal on Integrated Management of Occupational Health and the Environment* **3**: 1–22; Martinelli LA and Filoso S (2008) Expansion of sugarcane ethanol production in Brazil: environmental and social challenges *Ecological Applications* **18**: 885–98.
232 Dr Ben Richardson, responding to the Working Party's consultation.
233 Smeets E, Junginger M, Faaij A *et al.* (2008) The sustainability of Brazilian ethanol: an assessment of the possibilities of certified production *Biomass and Bioenergy* **32**: 781–813.
234 UNICA (2008) *What will be the social consequences of mechanizing the sugarcane harvest?*, available at: http://english.unica.com.br/FAQ/.
235 Richardson B (2009) *Sugar: refined power in a global regime* (Basingstoke: Palgrave Macmillan), p187.
236 Sawyer D (2008) Climate change, biofuels and eco-social impacts in the Brazilian Amazon and Cerrado *Philosophical Transactions of the Royal Society B* **363**: 1747–52.
237 Smeets E, Junginger M, Faaij A *et al.* (2008) The sustainability of Brazilian ethanol: an assessment of the possibilities of certified production *Biomass and Bioenergy* **32**: 781–813.
238 Amnesty International (2008) *Brazil – Amnesty International report 2008*, available at: https://www.amnesty.org/en/region/brazil/report-2008#.

up to two years to place a company on the list, and the legality of a public list is frequently challenged, with companies being able to obtain injunctions to their addition.

Effects on food prices

2.33 Like US corn ethanol, Brazilian ethanol production was discussed as a contributor to the spike in food prices, including sugar, experienced in 2008, and was thus a focus of the 'food versus fuel debate'. However, the picture appears to be positive with regard to Brazilian sugar cane. The World Bank paper of 2008 cited above concluded that sugar cane bioethanol did not raise sugar prices significantly.[239] Furthermore, the argument has been made that sugar is in general only regarded as a necessity by those with higher incomes, who are more able to cope with rising food costs.[240] It has also been suggested that the indirect impact of sugar cane bioethanol production on staple foods could be minimal. For example, the projected increase in land area planted with sugar cane by 2020 has been described as having potentially little or no impact on areas used to produce food or areas occupied by natural forest.[241] In addition, a study into the dLUC and iLUC effects of sugar cane production found that between 2002–2006 and in states where sugar cane production increased, the area dedicated to other crops also increased (with the exception of São Paulo).[242] A study by the Brazilian research unit, Fundação Getulio Vargas, on the effects of biofuels on grain prices found that the major reason for the rise in food prices was speculation on futures markets, stimulated by increased demand coupled with low grain stocks due to bad weather conditions and poor harvests. It concluded that there was no significant correlation between Brazilian sugar cane cultivation and average grain prices.[243]

Case study III: Biodiesel from palm oil in Malaysia

Background

2.34 Malaysia is the second largest producer of palm oil in the world. In 2009, it produced approximately 17.6 million tonnes of crude palm oil.[244] The main reasons for biofuels production were both economic and agricultural development, and energy security. To these ends, Malaysia has undertaken research and development on biodiesel derived from palm oil since 1982. The government research agency, the Malaysia Palm Oil Board, is continually improving biodiesel production technologies. The existing research and development capacity, a plentiful supply of palm oil feedstock, the eagerness of the palm oil industry to begin biodiesel production, and foreign investor interest have all supported the Malaysian Government's intention to develop biodiesel,[245] and export is becoming increasingly attractive to domestic palm oil companies.[246]

Legislation and policy

2.35 The Malaysian Government has introduced policies and legislation to encourage both the production and use of palm oil biodiesel (see Box 2.10), and production can be assumed to be increasing. It has been reported that in 2009, Malaysia exported approximately 288 million litres

239 Mitchell D (2008) *A note on rising food prices*, available at: http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2008/07/28/000020439_20080728103002/Rendered/PDF/WP4682.pdf, p17.

240 Richardson B (2009) *Sugar: refined power in a global regime* (Basingstoke: Palgrave Macmillan), pp181–2.

241 Matsuoka S, Ferro J and Arruda P (2009) The Brazilian experience of sugarcane ethanol industry *In Vitro Cellular & Developmental Biology* **45**: 372–81.

242 Nassar AM, Rudorff BFT, Antoniazzi LB *et al.* (2008) Prospects of the sugarcane expansion in Brazil: impacts on direct and indirect land use changes, in *Sugarcane ethanol: contributions to climate change mitigation and the environment*, Zuurbier P and van de Vooren J (Editors) (The Netherlands: Wageningen Academic Publishing), p89.

243 Fundação Getulio Vargas (2008) *Food price determining factors*, available at: http://virtualbib.fgv.br/dspace/bitstream/handle/10438/6947/326.pdf?sequence=1.

244 Malaysian Palm Oil Board (2009) *Production of crude palm oil for the month of December 2009 Jan – Dec total*, available at: http://econ.mpob.gov.my/stat/web_report1.php?val=200904.

245 Global Agricultural Information Network (2009) *Malaysia – Biofuels annual – annual report 2009*, available at: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/General%20Report_Kuala%20Lumpur_Malaysia_6-12-2009.pdf.

246 Ibid.

of biodiesel. In 2009, 21 biofuel companies were in operation, with several additional plants under construction.[247] However, currently domestic take-up is poor.[248]

Box 2.10: Biofuels policy in Malaysia

In March 2006, the National Biofuel Policy was implemented[249] "to ensure healthy development of the biofuel industry",[250] particularly biodiesel from palm oil. This is in line with Malaysia's Five-Fuel Diversification Policy, a national policy to promote renewable energy as the fifth fuel alongside fossil fuels (oil, gas and coal) and hydropower. The policy has two goals: i) "Use of environmentally friendly, sustainable and viable sources of energy to reduce the dependency on depleting fossil fuels;" and ii) "Enhanced prosperity and well-being of all the stakeholders in the agriculture and commodity based industries through stable and remunerative prices."[251]

The Malaysian Biofuel Industry Act 2007[252] provides for the mandatory licensing of activities relating to biofuels; however, the introduction of a mandatory B5[253] blend has been delayed.[254]

The Malaysian Government also supports the production of biodiesel through the construction of biodiesel plants. Under the Promotion of Investments Act 1986,[255] biodiesel is listed as one of the products or activities to be eligible for consideration for the Pioneer Status or Investment Tax Allowance. Pioneer Status grants the company tax exemption on 70 per cent of the income derived from biodiesel production for 5 years.[256] Subject to meeting certain criteria, biodiesel projects may also be considered for incentives for strategic or high technology projects, or incentives for commercialisation of research and development findings from the public sector in resource-based industries.[257] Furthermore, to encourage the domestic palm oil processing industry, the Malaysian Government taxes exports of crude palm oil but does not tax processed palm oil or biodiesel. For imports, there is a five per cent duty levied on processed palm oil.[258]

Problems associated with palm oil biodiesel

2.36 Palm oil biofuels production in Malaysia has raised significant concerns, both domestically and abroad. Some of the problems are associated with palm oil production in general, including deforestation, loss of biodiversity and infringement of workers' rights. However, recently 95 per cent of the *increased* production of palm oil in Malaysia and Indonesia was attributed to the growing demand for biodiesel[259] and thus, problems prevalent in palm oil production are likely to occur in palm oil biodiesel production as well. Other problems such as impact on food security are also relevant to biodiesel production. It is worth noting that palm oil is used in many types of produce such as food and cosmetics, so that increased demand for palm oil for biodiesel production leads to an increase in price for other vegetable oils also used for these purposes.

[247] Biodiesel Magazine (1 Sep 2010) *Global biodiesel production and market report*, available at: http://www.biodieselmagazine.com/articles/4447/global-biodiesel-production-and-market-report.

[248] Global Agricultural Information Network (2010) *Malaysia – Biofuels annual – annual report 2010*, available at: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Kuala%20Lumpur_Malaysia_7-16-2010.pdf.

[249] Ministry of Plantation Industries and Commodities Malaysia (2006) *The national biofuel policy*, available at: http://www.americanpalmoil.com/pdf/biodiesel/Malaysia%20Biofuel%20Policy.pdf.

[250] Ibid., p3.

[251] The policy has five strategic thrusts: (i) *Transport*: B5 diesel will be made available for transport throughout the country; (ii) *Industry*: B5 diesel will be supplied to the industrial sector; (iii) *Technology*: R&D and commercialisation of biofuels technologies will be effected and adequately funded by both the government and private sectors; (iv) *Export*: The establishment of facilities for producing biofuels for export will be encouraged; (v) *Environment*: Increased use of biofuels will enhance the quality of the environment. To these ends, the policy outlines short, medium and long term goals. http://www.americanpalmoil.com/pdf/biodiesel/Malaysia%20Biofuel%20Policy.pdf, p4, pp6-7, p9.

[252] Act 666 Malaysian Biofuel Industry Act 2007.

[253] 5 percent processed palm oil and 95 percent petroleum diesel.

[254] Global Agricultural Information Network (2010) *Malaysia – Biofuels annual – annual report 2010*, available at: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Kuala%20Lumpur_Malaysia_7-16-2010.pdf.

[255] Promotion of Investments Act 1986.

[256] Ministry of Finance Malaysia (2008) *Pioneer status*, available at: http://www.treasury.gov.my/index.php?option=com_content&view=article&id=704&Itemid=201&lang=en.

[257] Ibid.

[258] Global Agricultural Information Network (2010) *Malaysia – Biofuels annual – annual report 2010*, available at: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Kuala%20Lumpur_Malaysia_7-16-2010.pdf.

[259] United Nations Environment Programme (2009) *Towards sustainable production and use of resources: asessing biofuels*, available at: http://www.unep.fr/scp/rpanel/pdf/assessing_biofuels_full_report.pdf, p64.

This price increase could drive further expansion of production (for example, palm oil in South-East Asia or soybean in Brazil), thus potentially increasing the scale of negative effects.

2.37 *Conversion of forestland and associated loss of biodiversity*: Concern has arisen over the effect of oil palm expansion on Malaysian forestland and its biodiversity. A study in 2008 argued that the conversion of primary forests and some secondary (logged) forests to oil palm plantations may significantly reduce biodiversity, for example by decreasing the species richness of forest birds and butterflies.[260] The same study also found that during the period 1990–2005, between 55 and 59 per cent of the oil palm expansion in Malaysia involved the conversion of forests, most likely secondary or plantation forests. The authors thus concluded that the conversion of secondary forests (or primary forests) to oil palm plantations has detrimental impacts on South-East Asia's biodiversity. The potential impacts of lost forestland and biodiversity in this region are particularly significant given that South-East Asia contains a significant proportion of the world's remaining tropical forests which are home to many rare species.[261]

2.38 There are worries that deforestation in Malaysia, driven by oil palm plantation expansion, could lead to the extinction of rare species such as the orang-utan of Borneo (the island split between Malaysia, Indonesia and Brunei) through loss of habitat. It has been assumed that, concurrent with an annual forest loss of 1.7 per cent in Borneo, there was a loss of orang-utan habitat at an annual rate of approximately 1.7 per cent during 2002–2008.[262] Furthermore, the threat of 'population fragmentation' has emerged.[263] In Borneo, large swathes of jungle have been replaced with oil palm plantations and this has been cited as leading to the orang-utan population fragmentation,[264] giving rise to the risk of inbreeding or orang-utans becoming lost in the oil palm plantations. If orang-utans damage the oil palm fruits, they are also at risk of being hunted and killed by plantation managers.

2.39 *Deforestation, peatland conversion and GHG emissions:* As part of the debate surrounding LCA and GHG emissions from dLUC and iLUC as discussed above, in 2008 a study estimated the extent of 'carbon debts' (the amount of carbon dioxide gas released during the first 50 years of land conversion) and how long it would take to repay these for: i) Indonesian/Malaysian lowland tropical rainforest converted for palm oil biodiesel production; and ii) Indonesian/Malaysian peatland tropical rainforest converted to palm oil biodiesel production.[265] The conversion of lowland tropical rainforest would create a carbon debt that took approximately 86 years to repay. Until this point, the production and use of palm oil biodiesel would actually generate greater GHG emissions than the refining and use of an energy-equivalent amount of petroleum diesel. Owing to the carbon debt from vegetation and peat decomposition, the carbon debt for conversion of peatland tropical rainforest would take approximately 423 years to repay. The authors warned: "Our analyses suggest that biofuels, if produced on converted land, could, for long periods of time, be much greater net emitters of [GHGs] than the fossil fuels that they typically displace." In Malaysia and Indonesia, there is also the wider problem of illegal logging, which at current levels poses significant threats to the environment and local communities.

2.40 *Land rights issues:* There have been accusations of so-called 'land grabs' by palm oil producers leading to the clearing of land and the displacement of indigenous tribes. An investigation into palm oil production in Sarawak, the Malaysian state in Borneo, was carried out in 2009[266] and a

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260 Koh LP and Wilcove DS (2008) Is oil palm agriculture really destroying tropical biodiversity? *Conservation Letters* **1**: 60–4.
261 Indeed, a 'biodiversity hotspot' – that is an area containing high concentrations of endemic species and undergoing severe levels of habitat loss – covers almost all of Malaysia: Conservation International (2007) *Biodiversity hotspots: Sundaland*, available at: http://www.biodiversityhotspots.org/xp/hotspots/sundaland/Pages/default.aspx.
262 Wich SA, Meijaard E, Marshall AJ *et al.* (2008) Distribution and conservation status of the orang-utan (*Pongo* spp.) on Borneo and Sumatra: how many remain? *Oryx* **42**: 329–39.
263 This is when a species population becomes fragmented geographically due to the breaking up of its habitat.
264 The Independent (24 Oct 2009) *Orangutans struggle to survive as palm oil booms*, http://www.independent.co.uk/environment/orangutans-struggle-to-survive-as-palm-oil-booms-1808700.html.
265 Fargione J, Hill J, Tilman D, Polasky S and Hawthorne P (2008) Land clearing and the biofuel carbon debt *Science* **319**: 1235–7.
266 Stickler A (8 Dec 2009) *The end of the jungle?*, available at: http://news.bbc.co.uk/today/hi/today/newsid_8400000/8400852.stm.

member of an indigenous tribe reported: "They just simply come and bulldoze our farm and our coco trees…They never come to us, to talk to us about this. We tried to negotiate with them but what they say to us [is] they have more right than us here." Concerns over the palm oil producer's impact on the local water supply through use of fertiliser, pesticides and herbicides were also voiced. Tribes that have been affected have mounted a legal challenge to regain the rights to their land. However, the Cabinet Minister for Land Development in Sarawak asserted that the land "belongs to the government" but that "if it is indeed their land, the law of the land will take care of that" citing cases where land has been wrongly taken by the Government and returned to those who have the land rights. The palm oil producer IOI[267] has denied the accusations, asserting that it has "never evicted nor forced any natives from their lands. Immediately after taking over the company IOI initiated meetings with the native leaders to resolve the unsettled conflict. Some accepted ex-gratia payments and willingly handed over their land." This is a continuing problem: only recently, tribes in Sarawak reported that forestland was being cleared and felled for oil palm plantations, allegedly without their consent.[268]

2.41 Land rights conflicts lead on to concerns that subsistence economies are being disrupted. In 2008, civil society groups reported that 2.8 million hectares of predominantly forestland in Sarawak had been licensed out to logging groups[269] without taking account of communities who exercise so-called Native Customary Rights (NCRs) to the land.[270] NCRs are important to those who exercise them, since they rely on the land for food, medicines and construction materials.

2.42 There have also been reports that communities in Borneo who decide to become part of the oil palm expansion are being locked into considerable debts to the oil palm companies that come into the area.[271] With few alternative economic opportunities, some are eager to participate and acquire small plots of land. Money is borrowed at high interest rates from the oil palm company for seeds and other agricultural supplies. However, the plots of land take seven years to produce fruit, and during this time further agricultural resources are required, which are purchased from the company. When the land becomes productive, the level of income is low so these small holders, with the large start-up costs, can end up perpetually indebted.

Biofuel policy changes following controversies

> **"…we are disappointed to note that the European Commission recently ruled out imposing binding EU-wide sustainability criteria for biomass, offering member states recommendations for national action instead."**[272]

> **"The EU regulation (RED) is a good first step but without imposing any requirement for social aspects, it remains incomplete. Similarly, the policies developed in the United States lack a lot of requirements re the environment and people."**[273]

2.43 These controversies surrounding biofuels production have in some cases influenced recent biofuels policy making. The Brazilian case shows that some issues, such as land destruction and water pollution, can be tackled by policy initiatives, and Brazilian land zoning today includes rather strict criteria for protection of these resources. Europe also took note of the debates surrounding food security and LCA and an initial – some say rushed – introduction of legislation

[267] IOI Group is a large palm oil producer from Malaysia. IOI Group (2011) *About us*, available at: http://www.ioigroup.com/corporateinfo/corp_aboutus.cfm.
[268] WiredGov (9 Dec 2010) *Double 'green energy' threat to Borneo tribes' rainforest*, available at: http://www.wired-gov.net/wg/wg-news-1.nsf/lfi/DNWA-8BYBQG.
[269] Friends of the Earth International (2008) *Malaysian palm oil – Green gold or green wash?*, available at: http://www.foei.org/en/resources/publications/agrofuels/2008/malaysian-palm-oil-report, p5
[270] World Rainforest Movement (Sept 2008) *Malaysia: Those who lose in the oil palm business*, available at: http://www.wrm.org.uy/bulletin/134/viewpoint.html#-%20Malaysia:%20Those%20who%20lose%20in%20the%20oil%20palm%20business.
[271] Mongabay News (2009) *The social impact of oil palm in Borneo*, available at: http://www.mongabay.com/borneo/borneo_oil_palm.html.
[272] The Society of Biology, responding to the Working Party's consultation.
[273] Anonymous respondent, responding to the Working Party's consultation.

to encourage biofuels within the energy mix was followed by a reassessment, prompted by these multiple concerns about unintended consequences.

2.44 In the UK, the 2008 *Gallagher Review*,[274] commissioned by the UK Government, highlighted the uncertainties surrounding the environmental and social impacts of biofuels production (including dLUC and iLUC, and food security), and urged the Government to proceed with caution. The Renewable Transport Fuel Obligations (Amendment) Order 2009 (RTFO (Amendment) Order 2009)[275] subsequently came into force. This slowed the rate at which target levels – set out by the RTFO – increased, with the date for achieving the target of five per cent replacement of road vehicle fossil fuel moving from 2010 to 2013.

2.45 European policy making was similarly affected by concerns over environmental impacts, food security, human rights violations and, in particular, the debates over LCA. The Renewable Energy Directive (RED)[276] was adopted in recognition of these concerns, repealing the 2003 Biofuels Directive.[277] It set a mandatory target for each Member State (10 per cent of final energy consumption in transport by 2020) but set out some mandatory sustainability criteria. These included achieving GHG emissions savings[278] and not making use of raw materials that originated from land of high biodiversity value.[279] Furthermore, raw materials should not originate from either land with a high carbon stock[280] or land that was once peatland.[281] The European Commission (EC) is still working on a proposal for inclusion of iLUC into LCA of overall GHG emissions.[282] The RED also placed a requirement on the EC to report every two years on the sustainability in Member States and third countries[283] of increased biofuels demand, as well as on the impact of European policy on the availability of food (particularly in developing countries) and wider development issues including land and labour rights.[284]

2.46 US legislation has undergone a similar process. The RFS program, as required by EISA of 2007,[285] stated that biofuels must account for at least 36 billion gallons (approximately 136 billion litres) of annual US fuel supply by 2022, with 21 billion gallons from lignocellulosic biofuels[286] (the annual consumption of motor gasoline (petrol) in the US in 2007 was approximately 625 billion litres[287]). These numbers represent a nine-fold increase from the amount of biofuels produced in 2006. Following the debate around iLUC, the RFS program was reconsidered, and the EPA recently stated that "significant" effects of iLUC should be part of the LCA of biofuels.[288]

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[274] Renewable Fuels Agency (2008) *The Gallagher review of the indirect effects of biofuels production*, available at: http://www.renewablefuelsagency.gov.uk/sites/renewablefuelsagency.gov.uk/files/_documents/Report_of_the_Gallagher_review.pdf.

[275] Office of Public Sector Information (2009) The Renewable Transport Fuel Obligations (Amendment) Order 2009, available at: http://www.opsi.gov.uk/si/si2009/uksi_20090843_en_1.

[276] Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16.

[277] Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport [2003] OJ L123/42.

[278] Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16, art 17.2.

[279] Ibid., art 17.3.

[280] Ibid., art 17.4.

[281] Ibid., art 17.5.

[282] Recently, a report has been published, discussing some future policy options, see: European Commission (2010): *Report from the Commission on indirect land-use change related to biofuels and bioliquids*, available at: http://ec.europa.eu/energy/renewables/biofuels/doc/land-use-change/com_2010_811_report_en.pdf

[283] That is countries which are neither Member States nor Associated States (a country that contributes financially to the Community's research programme, and in return receives funding similarly as Member States).

[284] Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16, art 17.7.

[285] Energy Independence and Security Act of 2007.

[286] Currently, the lignocellulosic mandate is not enforced.

[287] US Energy Information Administration (2010) *International energy statistics*, available at: http://tonto.eia.doe.gov/cfapps/ipdbproject/iedindex3.cfm?tid=5&pid=62&aid=2&cid=regions&syid=2005&eyid=2009&unit=TBPD.

[288] For example, see: US Environmental Protection Agency (2010) *EPA finalizes regulations for the national Renewable Fuel Standard program for 2010 and beyond*, available at: http://www.epa.gov/oms/renewablefuels/420f10007.pdf, p5.

2.47 The landscape of biofuels policy is not static, however, and these policy changes by no means represent the conclusion of the debate.[289] More evidence is required before the effectiveness of the policy changes can be adequately assessed. In addition, there continues to be political scrutiny of the effectiveness of policy, as illustrated by responses to the Working Party's public consultation.

Current biofuels: the promise and the problems

2.48 When they were first discussed following growing awareness of climate change and dwindling oil supplies, biofuels appeared to promise a great deal. Indeed, the expectation was that they would solve some of the greatest challenges of today's world. In particular, it was thought that they would provide a source of fuel that is renewable and carbon neutral and which would provide a source of revenue for farmers. In the imagination of some, they were thus going to provide significant revenue from a 'clean' technology, as well as endless sources of fuel without emitting the GHGs co-responsible for climate change. If not a magic solution, they were certainly regarded by some as a 'green' answer to many problems. Even the former US President, George W. Bush, not known to be a strong champion of green issues, was entranced by the expected possibilities of biofuels and promised his fellow Americans that: "the best way and the fastest way to replace oil is to expand the use of ethanol. Ethanol is good for our rural communities. It's good for economic development for rural America. You know, new bio-refinery construction creates jobs and local tax revenues…Ethanol is good for the environment. I keep emphasizing that we can be good stewards of our environment and at the same time continue with our economic expansion."[290]

2.49 Our case studies also show vividly that there were powerful incentives for each of the governments to support the introduction of the particular biofuel in their country. The promises regarding energy security, climate change mitigation and economic development offered by the biofuels were seen to justify policy instruments, standards and subsidies that supported commercial biofuels production, and there is little doubt that, in all three cases, biofuels can be seen as an example of policy-driven economic development.

2.50 However, experience has shown that the promise is less certain than was once thought, and biofuels involve significant problems. As demonstrated in the case studies, claims about carbon neutrality are contested, and this continues to pose challenges to developers and producers. There are also concerns over food security and food prices. The scale of these is, however, debatable. Biofuels appear to be one contributing factor to changing food commodity prices, affecting vulnerable countries and populations. As shown above, there are several other factors which also play important roles in destabilising food prices. Blaming food price spikes on biofuels production alone – a frequent argument in our public consultation – would appear to be one-sided. That said, there is clearly a potential for more serious effects as biofuels production increases. Moreover, the rights of farmers, farm workers and land holders, particularly for vulnerable populations, have already been threatened or violated: this is likely to continue. There have also been severe environmental consequences, including pollution and the destruction of biodiversity through, for example, the destruction of rainforest, following large-scale implementation of biofuels production. Conversion of existing agricultural land to biofuels has led in some cases to iLUC, involving deforestation and depletion of scarce water resources, and air pollution has been a problem in some cases.

2.51 These problematic effects have had major political and social repercussions, with protests against biofuels sometimes involving violence in the streets (e.g. the tortilla riots mentioned above). For some commentators and activists, the backlash against the use of biofuels has

[289] Ninni A (2010) Policies to support biofuels in Europe: The changing landscape of instruments *AgBioForum* **13**: 131–41.
[290] The Washington Post (25 Apr 2006) *Bush delivers speech on renewable fuel sources*, available at: http://www.washingtonpost.com/wp-dyn/content/article/2006/04/25/AR2006042500762.html.

been severe. The technology heralded as a potential all-round solution to many problems has been accused of harms ranging from extinguishing the orang-utan to pushing the poorest even further into poverty, thus “driving a global human tragedy”.[291] While some of this criticism is as one-sided as the enthusiastic approval of the early days, there have no doubt been many harmful effects.

2.52 In view of this recent history of biofuels production, there is an urgent need to look at the issues openly, in the light of new technical developments, and with a clear statement of principles governing any future implementation and expansion. In Chapter 3, we discuss new biofuels, involving improved technologies for production, processing and distribution, which are being developed with a view to mitigating the problems associated with current biofuels. We then go on to propose an ethical framework to guide improved decision-making processes at government, industry and societal level, both for the development of new biofuels and for continuing production and use of current biofuels without harming people or the environment.

[291] Cited in The Guardian (15 Feb 2010) *EU Biofuels significantly harming food production in developing countries*, available at: http://www.guardian.co.uk/environment/2010/feb/15/biofuels-food-production-developing-countries.

Chapter 3

New biofuels – scientific developments

Chapter 3 – New biofuels – scientific developments

Box 3.1: Overview

The development of new biofuels technology is a rapidly growing field. New biofuels are expected to contribute to efforts to reduce net greenhouse gas emissions, improve energy security and aid development, while at the same time circumventing the shortcomings identified for some current biofuels, as discussed in Chapter 2. The unifying principles of development of new biofuels centre on the use of abundant feedstocks that can be produced without harm to the environment or local populations, with minimal competition with food production and minimal input of resources such as land, and that can be processed efficiently to yield high-quality liquid biofuels that are deliverable in sufficient quantities.

Various feedstocks have been proposed, each of which has its own challenges at each stage in the production pathway. In Chapter 3, we discuss continuing developments in production and processing for some of the main proposed feedstocks. The coverage is illustrative rather than exhaustive, discussing the examples of lignocellulosic and algal biofuels.

Lignocellulosic biofuels
Lignocellulosic biofuels use all of the plant instead of just the starch or sugary parts. Residue products from arable food agriculture, such as straw, could be used as feedstocks. In this way, food crop plants could become effectively dual-use, producing both food and fuel. A second option is to use plants grown solely for the production of lignocellulosic biofuels, such as trees and grasses (e.g. willow, poplar, switchgrass and miscanthus).

In addition to the greater utilisation of biomass compared with biofuels produced from food crops, there is significant potential to improve feedstock characteristics such as yields, water use, and pest and frost resistance using advanced plant breeding strategies and genetic modification. However, technology in this field is mostly still at the research and development stage. Moreover, lignocellulosic biofuels require more sophisticated processing than current biofuels, and this is currently very costly. However, given further technological advances, there are options to improve efficiency and bring down costs significantly.

Algal biofuels
Algae constitute a diverse group of aquatic photosynthetic organisms that produce an equally diverse range of chemicals, including an array of oils that can be used to produce biodiesel, avoiding some of the technical challenges of converting lignocellulose to liquid fuels. They do not require freshwater and can be cultivated in wastewater or sea water, and it is expected that under optimal conditions they will produce high yields. Algae can be cultivated in open ponds or closed photobioreactors, or in hybrid systems. Currently, the production of algal biofuels is experimental, and costs are very high. Again, there is significant potential for improvements of feedstocks and processing, for example using genetic modification or synthetic biology.

In the two final sections, Chapter 3 offers a brief description of both jatropha – a novel feedstock that has recently gained attention as a crop for developing countries – and the biorefineries approach, which aims to process and refine biofuels from a variety of sources and make use of as many of the by-products as possible.

Introduction

3.1 The previous chapters laid out the issues associated with current biofuels. At the heart of concerns about some biofuels are claims about their inefficiency and lack of convincing greenhouse gas (GHG) emissions savings, environmental degradation through deforestation, high-input cultivation using large amounts of fertiliser and taking up significant amounts of land, and competition with food production. Many of the issues discussed with respect to biofuels production have now been widely recognised (see Chapter 2). However, with the drivers as discussed in Chapter 1 still as forceful as ever, interest in liquid biofuels has not diminished. On the contrary, there is currently a great deal of activity to create a new generation of biofuels.

3.2 There are greater hopes that these new biofuels can contribute to efforts to reduce net GHG emissions and thus to mitigate climate change, and to contribute to energy security and development, while at the same time circumventing the shortcomings identified for some of the current biofuels established today. This chapter describes some of the most prominent new developments in biofuels science and discusses their potential for avoiding the problems of some current biofuels.

New biofuels

3.3 The unifying principles of development of new approaches to biofuels centre on abundant feedstocks that:

- can be produced without harming the environment or local populations;
- are in minimal competition with food production;
- need minimal resources, such as water and land;
- can be processed efficiently to yield high-quality liquid biofuels; and
- are deliverable in sufficient quantities.

3.4 Proposed solutions to the problems of established biofuels from food crops are focused on alternative feedstocks, but these are more problematic with respect to the associated technologies required to process them efficiently. There are several main proposals for feedstocks, each of which has its own challenges at each stage in the production pathway. In the following sections, we will give an overview of some of the new approaches in science and industry to develop biofuels. Our coverage is illustrative rather than exhaustive and discusses lignocellulosic and algal biofuels. We have selected these two technologies because they are the dominant approaches currently under investigation.

Lignocellulosic biofuels

Feedstocks

3.5 The edible 'food' parts of the plants used for current biofuels production represent only a small proportion of the carbon fixed by the plant – albeit one which is converted relatively easily into fuel. Most of the dry mass of the inedible parts of the plants is made up of cell walls, which are an abundant source of biomass. Making use of these parts for fuel production could thus circumvent direct competition with food. Many new approaches are therefore aimed at developing methods that allow the cell walls, i.e. the lignin and cellulose in the cell walls, to be used for the production of so-called lignocellulosic biofuels, which are often referred to as 'second generation' biofuels.

3.6 Lignocellulosic feedstocks that appear promising include agricultural and municipal residues and wastes, currently unused parts of established biofuels crops, and dedicated biofuels crops. We will focus on two main proposals for lignocellulosic feedstocks. The first option is to use residues from arable food agriculture, such as straw, as feedstock enabling crop plants to become effectively dual-use,[292] producing both food and fuel. A second option is to use plants such as trees and grasses which are grown solely for the production of lignocellulosic biofuels. This approach involves specialist biofuels crops, where breeding programmes and agricultural systems can focus on optimal feedstock production, without the constraints of food production inherent in dual-use crops.

Dual-use crops

3.7 There is a long list of agricultural lignocellulosic residues that could be processed to produce biofuels, including straw and stover from food crops such as wheat, barley and corn, and

[292] Note that 'dual-use' is used as a neutral term here, unlike its use in discussions about defence/security, where it can denote both beneficial and malevolent applications of a technology.

forestry waste. In 2006, an estimated 2.9 million tonnes of straw was available to the UK after traditional uses had been taken into account. In addition, the total amount of available forestry residues is estimated to be approximately 2 million 'oven-dried tonnes'[293] per year, again after accounting for traditional uses.[294] This represents a potential source for fuel production which does not make any demands on food directly or indirectly, as no additional land other than the land already in use is necessary.

3.8 The efficient conversion of lignocellulose to biofuels is an area of very active research at present[295] and the success of lignocellulosic biofuels is critically dependent on developing efficient processing. For dual-use crops where a substantial volume of residues derives from a specific agricultural source such as straw, there is interest in improving its quality for processing, for example by modifying cell wall structure, without compromising food production (discussed below in Box 3.3 on biofuels crop improvement strategies).

3.9 An additional issue with agricultural residues is their limited supply. As straw can be used to provide organic amendment to soil to maintain good soil condition, some suggest that a maximum of only 40 per cent of straw should be used in ethanol production or other industrial purposes.[296] Moreover, farmers require compensation for parting with their straw, as it is not a cheap waste product but rather has economic value (calculations, taking into consideration the current cost of buying in replacement fertiliser for the nutrients exported in straw and the balance of costs in baling and removing wheat straw, come out at a minimum wheat straw value of around £113 per hectare or £32 per tonne). Therefore, although agricultural residues are highly attractive feedstocks, they are inherently limited in their supply, as well as in the degree to which they can be improved to achieve maximum energy recovery and yield liquid biofuels.

Dedicated lignocellulosic biofuels crops

3.10 Many of the constraints associated with using residues from arable food agriculture can be avoided by using dedicated biofuels crops. For dedicated biofuels crops, there is the prospect of breeding high-yielding crops with greater energy-conversion potential and which require minimum inputs. However, while dedicated crops do not lead to direct competition with food crops, the danger exists that agricultural resources – mainly land – are diverted away from food production, and that the overall demand for these resources intensifies. An important goal for dedicated biomass crops is therefore to be able to use land that is unsuitable for food agriculture ('marginal' land) or as part of a crop rotation programme ('idle' land; see Box 3.2).

Box 3.2: Type of land: 'marginal', 'idle' and 'additional' land

One of the main goals of new approaches to biofuels is to cultivate crops which can grow on land unsuitable for food agriculture, thus avoiding competition between food and fuel. This kind of land is often dubbed 'additional' land (i.e. it can be used without impacting on food agriculture), or 'marginal' land (i.e. it is land with a low carbon stock).

However, the reality of this is far more complex than calculating the number or acres of additional land or marginal land available for biofuels production. A plurality of terms is used to describe land types (e.g. there is also 'idle', 'subprime agricultural', 'degraded' land, etc.) and, although these terms are typically used to refer to the quality of land and its suitability for agriculture, in the absence of agreed definitions the terms tend to be used heterogeneously. For example, idle land has been used to refer to underused agricultural land, which may have a low carbon stock and low biodiversity, but it can also be used to refer to good-quality land that has never been used before, which therefore may have a high carbon stock and could also be used for food agriculture. Moreover, marginal land, even if unsuitable for food agriculture, might be otherwise important, for example in delivering ecosystem services.

This lack of definition increases the difficulty in evaluating how much suitable land is available for biofuels production. This was recognised in 2008 by the *Gallagher Review*, which established its own definitions for terminology used in its

[293] This is the mass of wood that has been completely dried, i.e. has zero moisture content.
[294] AEA Technology (2009) *Evaluation of opportunities for converting indigenous UK wastes to fuels and energy: report to the National Non-Food Crops Centre*, available at: http://www.nnfcc.co.uk/tools/evaluation-of-opportunities-for-converting-indigenous-uk-wastes-to-fuels-and-energy-report-nnfcc-09-012/at_download/file, p6.
[295] Various responses to the Working Party's consultation.
[296] Lafond GP, Stumborg M, Lemke R *et al.* (2009) Quantifying straw removal through baling and measuring the long-term impact on soil quality and wheat production *Agronomy Journal* **101**: 529–37.

report.[297] However, these definitions of "idle land" and "marginal or degraded land" still leave a lot of room for interpretation.

It is likely that, because land can be used for many purposes and because it often has a function even when it is *not* put to some particular use, even the development of crops which can grow on low-quality land will not entirely circumvent the problem of competition for land. However, while they are not the perfect solution that they have sometimes been promised to be, high-yielding crops with low input requirements certainly are one of the ways towards easing the pressures on land demand worldwide. Their development in biofuels might moreover provide valuable experiences and insights for other types of agriculture.

Voices from the consultation

"Use of marginal land is likely to have negative biodiversity impacts."[298]

"…most 'underutilized' lands are utilized for other purposes, and except for deserts, there are few wastelands available."[299]

"In some cases the agreement is to grow biofuels on 'idle' or 'marginal' land under the assumption that the unoccupied land is never used, which ignores groups such as nomadic herders who depend on land at certain times of the year."[300]

3.11 Focus on these characteristics has driven particular interest in perennial crops, which are nutrient-efficient and, once established, require no tillage. Pest-resistant dedicated biofuels crops are also a reasonable prospect because there is no need to breed out toxic compounds – produced by many plants in defence against pests – if such crops are not intended for the food chain.[301] However, since the production of animal feed from processing residues is often a desirable aspect of the biofuels life cycle assessment (LCA) as it adds favourably to the economic and GHG emissions balance, the advantages of feedstock specialisation just for biofuels production might be outweighed by the economic consequences of not yielding animal feed as a co-product.

3.12 In the development of novel, dedicated, non-food, biofuels feedstocks, such as those derived from perennial grasses and short rotation trees, the ideal would be to produce the highest energy yields possible with the lowest inputs in terms of water, fertilisers and pesticides, on the smallest amount of land that is otherwise unsuitable for food agriculture. Hence, a lot of activity currently surrounds improving yields in such crops, while reducing input needs and increasing stress tolerance (discussed in Box 3.3 below). In contrast to cereal crops, which have been domesticated for millennia and are the focus of significant research and development, perennial bioenergy crops have a limited history of breeding and development for yield improvement and other traits. Thus, there is the potential for energy yield increases in dedicated energy plants and, furthermore, there is a prospect of rapid progress given recent developments in advanced plant breeding strategies (APBSs; discussed below). Indeed, significant advances have already been made.[302]

3.13 The current focus, particularly in the UK, is on perennial native trees cultivated under short rotation coppicing (SRC), such as willow and poplar, and on foreign species of perennial grasses such as miscanthus and switchgrass. The crops can produce high biomass yields with limited nitrogen fertiliser inputs, which minimises pollution and improves their GHG emissions savings. The crops discussed below are among the most promising examples for temperate regions such as the UK. As well as providing energy, they could have some beneficial effects on ecosystem services. All perennials have high carbon dioxide sequestration, and SRC willow is

297 Renewable Fuels Agency (2008) *The Gallagher Review of the indirect effects of biofuels production*, available at: http://www.renewablefuelsagency.gov.uk/sites/renewablefuelsagency.gov.uk/files/_documents/Report_of_the_Gallagher_review.pdf, p33.
298 Anonymous respondent, responding to the Working Party's consultation.
299 Jonathan Gressel, responding to the Working Party's consultation.
300 Dr Thomas Molony, Centre of African Studies, University of Edinburgh, responding to the Working Party's consultation.
301 Pest resistance does not always mean that toxic compounds are present. Pest resistance can also be based on secondary metabolites normally produced in the plant but in different ratios or amounts.
302 Karp A and Shield I (2008) Tansley Review: bioenergy from plants and the sustainable yield challenge *New Phytologist* **179**: 15–32.

high in biodiversity and can also act as a riparian filter which helps to reduce run-off from arable land or be used for phytoremediation (i.e. treating environmental problems through the use of plants, for example removing toxins from contaminated soils).

Willow: technological potential and challenges

3.14 Willow (*Salix*) has a long tradition of cultivation in the UK for the production of wicker. It is a fast-growing tree and has some of the highest carbon dioxide exchange rates, light-use efficiencies and photosynthetic capacities of woody species; these are factors which can contribute to high yields and thus make willow an attractive crop for biofuels production. Willow is also promising as it can achieve high yields with low fertiliser and pesticide input. Furthermore, great genetic diversity exists (there are between 330 and 500 species of willow), which can be used in breeding programmes to improve yields further. To date, several studies have already achieved yield increases.[303] However, there are technological challenges. Willow requires water to achieve high yields; it is therefore only likely to be sustainable in areas where water is not limited. Poplar (*Populus*) is an alternative to willow as it shares several characteristics. However, it has less genetic diversity, can require more water than willow and can also be very susceptible to disease caused by rust.

Miscanthus: technological potential and challenges

3.15 Miscanthus species are perennial grasses that originate from East Asia. They constitute good feedstocks for biofuels production as they utilise a photosynthesis pathway (C4) which enables greater yields and water-use efficiency than, for example, willow or poplar. In addition, the growth efficiencies of miscanthus have been shown to be highest at the lowest nitrogen level used;[304] miscanthus could thus be grown on soils that would otherwise be unsuitable for arable agriculture. Although miscanthus originates from tropical regions, it can grow well across Western Europe, depending on the genotype grown and the climatic conditions.[305] In addition, there is potential for genetic improvement (e.g. to improve yields or to introduce additional traits such as drought tolerance), given that there is considerable genetic diversity within the genus that has mostly not yet been exploited.[306] Once again, however, there are some constraints. For example, advanced plant breeding programmes may – depending on the crop and trait desired – take some time to generate feedstocks, which is a limitation common to all biofuels feedstocks subjected to advanced breeding (discussed below). Despite high water-use efficiency, miscanthus yields are affected by water availability in soil,[307] and therefore the environmental sustainability of miscanthus plantations is dependent on ensuring adequate water supply. To this end, decisions regarding the situating of plantations must take account of soil and geological data.[308] Research has shown that, in the UK, miscanthus plantations are water-limited in some areas.[309]

Switchgrass: technological potential and challenges

3.16 A native species to the US, switchgrass (*Panicum virgatum*) shares a number of characteristics with miscanthus in that it too is a C4 grass and therefore is high yielding and has high water-use

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303 Karp A and Shield I (2008) Tansley Review: bioenergy from plants and the sustainable yield challenge *New Phytologist* **179**: 15–32.

304 Lewandowski I and Schmidt U (2006) Nitrogen, energy and land use efficiencies of miscanthus, reed canary grass and triticale as determined by the boundary line approach *Agriculture, Ecosystems & Environment* **112**: 335–46.

305 Clifton-Brown JC, Lewandowski I, Andersson B *et al.* (2001) Performance of 15 miscanthus genotype at five sites in Europe *Agronomy Journal* **93**: 1013–9.

306 Clifton-Brown J, Chiang Yu-C and Hodkinson TR (2008) Miscanthus: genetic resources and breeding potential to enhance bioenergy production, in *Genetic improvement of bioenergy crops*, Vermerris W (Editor) (New York: Springer), pp273–94.

307 Richter GM, Riche AB, Dailey AG, Gezan SA and Powlson DS (2008) Is UK biofuel supply from miscanthus water-limited? *Soil Use and Management* **24**: 235–45.

308 Ibid.

309 Ibid. Indeed, water use of miscanthus – despite being a C4 crop – has been found to be higher than that of willow owing to the dry leaves of the standing miscanthus winter crop intercepting rainfall (willow loses its leaves but miscanthus holds on to many of its leaves until harvest in early spring). Personal communication, Jon Finch, Centre for Ecology & Hydrology, UK.

efficiency. Yields of this species have been improved by more than 50 per cent through conventional breeding over the last 10 years, but they are still substantially lower than those of miscanthus. There is, however, considerable genetic variation in switchgrass, promising further opportunities to improve yields and introduce other traits advantageous to biofuels production. It has been suggested that switchgrass could potentially act as an 'entry crop' for biofuels production to help farmers cope with the transition from other perhaps more economic crops to biofuels feedstocks. For example, such entry crops could be grown on marginal land and would not require new machinery. They might not necessarily be desired in the long term but they could facilitate the economic transition from more traditional agriculture.[310] Switchgrass can be multifunctional and be used for grazing as well as for biofuels. In addition, it would not require new machinery and would be suitable for cultivation on marginal land.

Improving dedicated lignocellulosic crops

3.17 Most of the dedicated biofuels crops discussed above are currently subject to research and development to improve their characteristics as feedstocks for biofuels production. Targets for research centre on improving LCAs by improving technological aspects, and include:[311]

- maximising yield per unit area of land;
- reducing fertiliser requirements (although these are already lower than for food crops);
- reducing pesticide requirements;
- affording drought and/or other stress tolerance;
- improving ease of harvesting and storage;
- enhancing suitability for processing (e.g. production of digestive enzymes by plants, and modifying lignin); and
- ensuring health and safety in the production pathway.

3.18 This is a demanding list of properties but, given the genetic diversity available in these crops, increasing knowledge of the exact modifications required, and a variety of methods for altering traits (conventional, marker-assisted and genomics-assisted breeding, as well as genetic modification), there is optimism that dramatic progress can be made.

Technologies for the genetic improvement of biofuels crops

3.19 The basic principle of all plant breeding is that genetic variation within the species of interest is 'shuffled' by crossing different varieties. In the progeny of these crosses, offspring are identified that have improved performance for some characteristic beyond that found in the parental lines, and/or that combine multiple desirable characteristics that are present separately in the parents. The improvements in characteristics are achieved by bringing together genetic variation present in the parents in new combinations.

3.20 Two major factors limit the power of conventional plant breeding. The first is that the selection of lines with improved characteristics can be very labour- and time-intensive. It takes many years and fields of land and a lot of work to, for example, measure the yields of trees to compare the

310 Dr Gordon Allison, University of Aberystwyth, responding to the Working Party's consultation.

311 See, for example: Karp A and Shield I (2008) Tansley Review: bioenergy from plants and the sustainable yield challenge *New Phytologist* **179**: 15–32; Sticklen MB (2008) Plant genetic engineering for biofuel production: towards affordable cellulosic ethanol *Nature Reviews Genetics* **9**: 433–43.

progeny. The second problem is one that becomes progressively worse as breeding programmes proceed. For existing crop plants, which have been under selection for millennia, elite lines have been developed with exceptionally high performance in comparison with their ancestors, and genetic diversity within breeding populations has decreased over time. Under these circumstances, it becomes particularly difficult to introduce new traits not present in the breeding populations, even if they are present in wild relatives. For example, these might include resistance to a new pest strain or, as in the case of biofuels, new cell wall properties that have been lost from breeding stocks because they have not been of interest and therefore not previously selected for by breeders. Introducing traits from wild relatives into elite backgrounds is very time-consuming, difficult and labour-intensive because progeny of crosses between the elite line and the wild relative will have half their genes from the wild relative, effectively destroying the carefully constructed combination of genes in the elite line. To restore these gene combinations, individuals from the progeny carrying the desired trait from the wild relative must be back-crossed to the original elite line for many generations, each time diluting out the genes from the wild relative, while maintaining the one desired trait.

3.21 Various APBSs have been developed to overcome these problems. These take advantage of knowledge about the molecular genetic basis for particular traits, or detailed knowledge of the genomes of elite lines. If it is known that a particular trait, such as resistance to a particular fungal strain, is caused by a particular variant of a particular gene, then instead of having to identify lines in the progeny of crosses that have the desirable trait by infecting them all with the fungus and seeing which ones are less susceptible, the breeder can screen the lines when they are tiny seedlings to identify those with the desired gene variant by a relatively simple laboratory-based test. This is called marker-assisted breeding.[312] It can be effective even if the exact gene in question is not known, because genetic variation nearby on the chromosome, which is likely to be co-inherited with the desired trait, can be used instead.

3.22 More recently, as the cost of DNA screening has dramatically reduced, it has become possible to screen the progeny for many thousands of genetic variations simultaneously. This can speed up the reassembly of elite genomes following crosses with wild relatives, by allowing selection of plants that match closely the elite line at thousands of sites across the genome. This approach is called genomics-assisted breeding.[313] As knowledge about the relationship between genes and traits improves, genomics-assisted breeding can be used not only to speed up the selection of progeny with reassembled elite genomes but also to select lines with new desired combinations of genes.

3.23 These APBSs are in their infancy but they are sufficiently well established to give confidence that they will continue to accelerate breeding programmes substantially. Furthermore, they are built entirely on conventional, well-accepted crossing regimes and thus they have not triggered the concerns associated with genetic modification (discussed in Chapter 5). They are, however, currently very expensive and technically demanding, so it is mostly large multinational plant breeding companies that are exploiting them.

3.24 Meanwhile, genetic modification approaches also have much to offer in providing different solutions to the very same problems as conventional plant breeding. In particular, genetic modification provides an attractive solution to the problem of introducing single new traits into an elite line. Assuming a single gene that provides the trait is known, direct introduction of the gene into the elite background can circumvent many years of crossing. Furthermore, genes from entirely different species can be introduced, allowing traits not otherwise accessible to be added. For example, in the case of biofuels production, this might include the introduction of cell wall-modifying enzymes from microbes.

[312] Collard BCY and Mackill DJ (2008) Marker-assisted selection: an approach for precision plant breeding in the twenty-first century *Philosophical Transactions of the Royal Society B: Biological Sciences* **363**: 557–72.

[313] Varshney RK, Graner A and Sorrells ME (2005) Genomics-assisted breeding for crop improvement *Trends in Plant Science* **10**: 621–30.

Lignocellulose processing

3.25 Another challenge in producing new biofuels from the feedstocks described above is processing these into the fuel. Whatever the feedstock, lignocellulosic biofuels production is more difficult to achieve than converting the edible portions of food crops into fuel. Instead of being readily available for processing through relatively simple chemical processes, the sugars in the cell walls are polymerised (i.e. essentially 'locked') into chains and embedded with a component called lignin, making lignocellulose.

3.26 Generally, the biomass components of interest for biofuels production can be divided into three fractions: lignin, cellulose and hemicellulose. Lignin provides stability to plants and helps to protect them against microbial and enzymatic degradation. It provides the so-called 'recalcitrance of the cell wall',[314] which has to be overcome to release the sugars necessary for fermentation-based biofuels production. The other two fractions, cellulose and hemicellulose, are two types of sugar chain that differ in the diversity of their constituent sugars. As cell walls mature, the sugar chains become cross-linked with lignin forming a tough, waterproof resin. Many different compounds of lignin can be found in plants and this adds to the challenge in developing approaches to lignin degradation. However, the lignin itself is of significant value as it is composed of phenolic compounds that can provide a feedstock that is very similar to standard petrochemical feedstocks.

3.27 New lignocellulosic biofuels production aims to release more of the energy that is captured within the more recalcitrant fractions, as well as targeting the cellulose which is more readily processed. This is important as, altogether, these fractions constitute the majority of any readily grown biomass. In general, processing lignocellulose involves two main stages: pretreatment and conversion.[315] Lignocellulosic feedstocks need to be pretreated before they can be converted into biofuels. Pretreatment generates intermediates that are both easier to process, thus reducing subsequent conversion costs, and denser than the raw material, thus making it easier to transport and allowing for more centralised provision of subsequent processing steps and biofuels collection points. In most pretreatments, a mechanical digestion step is followed by biochemical pretreatment (lignocellulosis – using chemicals and enzymes, or microorganisms that produce enzymes) or thermochemical pretreatment (pyrolysis – burning in the absence of oxygen, or gasification – partial combustion).[316]

3.28 Intermediate products need to be converted to stable fuels through further conversion and refining using the appropriate method. Hydroprocessing can convert plant oil or bio-oil (produced by pyrolysis) into an end-product that can be refined in a conventional refinery.[317] Ways to hydrolyse a range of biomass will have to be developed as it is more economical to develop a strategy that could be applied to a range of feedstocks (thus enhancing applicability and mitigating potential shortages in supply.) Genetic modification of microorganisms to enable higher efficiency of digestion of lignocellulosic biomass or production of cheaper enzymes is a major target for current research, but work is also looking at processing into intermediates such as biobutanol, which can be produced from high-quality syngas (derived from gasification) using the bacterium *Clostridium acetobutylicum* as a catalyst.

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[314] Himmel ME, Ding S-Y, Johnson DK *et al.* (2007) Biomass recalcitrance: engineering plants and enzymes for biofuels production *Science* **315**: 804–7.

[315] For a review, see: The Royal Society (2008) *Sustainable biofuels: prospects and challenges*, available at: http://royalsociety.org/WorkArea/DownloadAsset.aspx?id=5501, pp20–8.

[316] The Royal Society (2008) *Sustainable biofuels: prospects and challenges*, available at: http://royalsociety.org/WorkArea/DownloadAsset.aspx?id=5501.

[317] Ibid.

Improving lignocellulose processing

3.29 Improving the processing (i.e. both pretreatment and conversion) of lignocellulose to obtain biofuels at a relatively low cost is very important in order for them to become an economically viable option. In addition, during processing, it is important to be mindful of water and chemical inputs, as well as outputs (toxic residues, soil and water pollution, etc.). Finally, energy and carbon inputs should be low, with as much carbon recycling as possible, and high energy outcomes, to contribute to a positive overall LCA and an optimum overall GHG emissions balance. Owing to these manifold challenges and the many different developments under way, it is currently not possible to determine the best or most successful processing strategy. There is significant potential to improve processing towards increased sustainability, cost-effectiveness and energy efficiency. Depending on the feedstocks and on other elements of the production process, it is most likely that several processing pathways will emerge. The advances detailed in Box 3.3, which include several biotechnological approaches, are therefore just examples of technologies under development to give an impression of the challenges and the potential for improving processing for new biofuels.

Box 3.3: Improving lignocellulosic processing

Improving biochemical processing of lignocellulosic biomass

Currently problems exist with inefficient cellulolysis (the breakdown of cellulose to release simple sugars), for example owing to the generation of lignin and hemicellulose-derived inhibitors.[318] Furthermore, current pretreatment strategies are costly.[319] Bioprospecting for enzymes from cell wall-digesting organisms – such as microbes from termite guts, the gribble[320] or fungi – is being used to isolate novel enzymes. For example, enzymes that digest polysaccharides, such as cellulases, are being sought with improved enzymatic activities. Lignin degraders such as white rot fungi are also important as these release vital energy and compounds that are more valuable than sugars. There are also programmes of research to develop cellulases with increased cellulase activity, and to lower their cost.[321]

Genetic modification of microorganisms to enable more efficient conversion of lignocellulose to ethanol is also a major research target.[322] For example, *Escherichia coli* has already been developed for improved fermentation of lignocellulose, and with a greater ethanol tolerance.[323] Ethanol concentrations increase as the fermentation process proceeds and can inhibit fermentation, thus requiring the costly and energy-intensive step of distillation. Increased ethanol tolerance reduces this need. Another example is the production of a genetically modified microbe that produces biobutanol using sugars from sugar cane, corn and wheat, and ultimately – it is intended – cellulosic feedstocks.[324] This technology is similar to current bioethanol production but makes use of a genetically modified microbe that produces butanol rather than ethanol. Butanol is more advantageous than ethanol as a biofuel in terms of energy content, combustibility, ease of transporting as well as miscibility with diesel.

Improving thermochemical processing of lignocellulosic biomass

Every step of the thermochemical pathway could benefit from further technological advances. However, developing these new technologies requires – at least initially – considerable capital input, without guarantees as to which pathways will turn out to be the most effective and energy-efficient process.

There is a lot of continuing activity to improve pyrolysis yields through different types of pyrolysis reactor, with particular attention to keeping the process energy efficient to maximise the net energy balance. Investigations are being aided by using thermo-analytical, chromatographic and other analytical techniques to scan the biomass before pyrolysis, to determine optimal conditions for the process. These same analytical approaches can also be applied to gasification, potentially resulting in purer gasification products. Several advances in gasifiers might also enable improvements in energy yields. The subsequent conversion stage is also undergoing research to help improve biofuels processing: for example, work is currently under way to develop Fischer–Tropsch reactors with greater outputs, and to improve Fischer–Tropsch catalysts.[325] It is suggested that some advanced thermochemical technologies that make use of lower

[318] Banerjee S, Mudliar S, Sen R *et al.* (2010) Commercializing lignocellulosic bioethanol: technology bottlenecks and possible remedies *Biofuels, Bioproducts & Biorefining* **4**: 77–93; Gray KA, Zhao L and Emptage M (2006) Bioethanol *Current Opinion in Chemical Biology* **10**: 141–6.

[319] Weng JK, Li X, Bonawitz ND and Chapple C (2008) Emerging strategies of lignin engineering and degradation for cellulosic biofuel production *Current Opinion in Biotechnology* **19**: 166-72.

[320] These are small organisms that are able to break down cellulose in wood to sugars.

[321] Banerjee S, Mudliar S, Sen R *et al.* (2010) Commercializing lignocellulosic bioethanol: technology bottlenecks and possible remedies *Biofuels, Bioproducts & Biorefining* **4**: 77–93.

[322] Ibid.

[323] Rubin EM (2008) Genomics of cellulosic biofuels *Nature* **454**: 841–5.

[324] BP, responding to the Working Party's consultation.

[325] Atkinson D (2010) Fischer-Tropsch reactors for biofuels production: new technology needed! *Biofuels, Bioproducts & Biorefining* **4**: 12–6.

temperatures and pressures, and are therefore less expensive, will be demonstrated in the UK during the first half of this decade.[326]

Technologies for the genetic improvement of microbes used in biofuels production
There is massive uncharted microbial diversity on the planet, with microbes living on the most unlikely sources of carbon, and hence able to digest and process even the most recalcitrant hydrocarbons. These microbes could offer solutions to many of the biochemical processing challenges found in biofuels production, both in lignocellulosic processing and in algae, described later in this chapter. However, as with crop plants, it is also the case that there is considerable potential for genetic improvement using genetic modification approaches. Furthermore, substantial systems engineering of microbial metabolism using synthetic biology strategies has been proposed as one way to improve biofuels production, for example by allowing the production of optimal or tailored biofuel molecules.[327]

'Synthetic biology' is used in various ways. At one end of the spectrum, genetic modification approaches in which several genes are introduced have sometimes been described under this heading. For example, introducing genes encoding several new enzymes into a microbe, thus allowing it to degrade a particular biomass compound through sequential steps, might be described as synthetic biology by some, and this could advance processing. However, a more common definition involves more whole-scale bioengineering, for example starting with a minimal microbial genome and adding much more substantial sets of genes, building in entire metabolic and catabolic networks designed to optimise the performance of the microbe for a specific task. This latter approach is still some way off but is potentially promising for the production of new biofuels.

Using algae to process lignocellulosic biomass
Another approach is the cultivation of a type of algae that is able to make use of sugar from both sugar cane and cellulosic feedstocks, and convert it to intermediates for biodiesel production.[328]

Estimated time frame to commercialisation

3.30 There is a great range in terms of the maturity of the technologies discussed in this section. While some are at the pilot stage, or nearing or entering commercial production, others have been reported from laboratories and are decidedly at the research and development stage. The field is diverse, with public institutions (such as universities), industry and public–private joint ventures all working in parallel. It is also a global community, with many advances being reported from research teams in emerging economies. Moreover, different supportive policies are in place around the world, some of which significantly influence the attractiveness to invest in new biofuels research and development, and thus the speed of development. In sum, it is very difficult to estimate when the production of biofuels from dual-use or dedicated energy crops will be possible at reasonable costs and on a sufficiently large scale to have a significant impact. A study conducted by the consulting company Accenture in 2009 analysed more than 100 companies, and interviewed scientists and over 30 companies. The study concluded that the uses of wastes or dedicated energy crops were promising in terms of cost and time to market.[329] However, whereas use of dedicated energy crops was deemed as scalable, there was some uncertainty over the use of wastes given that large-scale production would require collection and transport. Respondents to the Working Party's public consultation gave time estimates for lignocellulosic biofuels ranging between the next few years and 10 years:

> **"…we feel confident that both pretreatment and processing will be improved with the next 5 years. However to make commercial plants fully optimal may take 10 years."**[330]
>
> **"Some [biochemical conversion pathways] are likely to be commercialised in the next year or so, and [to] be economic by about 2013/2014."**[331]

[326] NNFCC, responding to the Working Party's consultation.
[327] Robert Henry, responding to the Working Party's consultation.
[328] BP, responding to the Working Party's consultation.
[329] Accenture (2009) *Betting on science: disruptive technologies in transport fuels – study overview*, available at: http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture_Betting_on_Science_Study_Overview.pdf, p16.
[330] Rothamsted Research, responding to the Working Party's consultation.
[331] Biotechnology and Biological Sciences Research Council Sustainable Bioenergy Centre (BSBEC), responding to the Working Party's consultation.

"By 2020 through a combination of enzyme cost reduction, capital cost optimisation, and feedstock yield improvement and cost reduction, it is projected that production costs [for use of energy grasses] will attain similar levels to Brazilian sugar cane ethanol."[332]

"According to key stakeholders interviewed during the [Sustainable Consumption Institute, University of Manchester] project, lignocellulosic technologies are in the prototype stage and will probably be commercially available by 2020."[333]

"5-year timescale [for syngas systems using wastes]?"[334]

Algal biofuels

Feedstock

3.31 An alternative biofuels feedstock which currently receives significant attention is algae. Algae constitute a diverse group of aquatic photosynthetic organisms that produce an equally diverse range of chemicals which have long been considered as biotechnological targets. There are two major categories of algae: macroalgae, familiarly known as seaweed, and microalgae, of which there are many different species that live as either single cells or colonies. It is the microalgal species that are being most intensively investigated as a possible source of biofuels; however, some also consider macroalgae as a promising potential feedstock.[335]

3.32 The production of algal-based biofuels (ABBs) – sometimes referred to as third generation biofuels – was first prompted by the energy crisis in the 1970s; and between 1978 and 1996 the US Department of Energy's Aquatic Species Program investigated the production of biodiesel from high lipid-content algae. Despite the significant knowledge produced from these studies, funding for this area of research was reduced, primarily owing to the lowering in price of crude oil. Recently, research on ABBs has re-emerged as an active area of research and development, funded by a number of the major energy companies as well as the US Government.[336]

3.33 Use of algae as a biofuels feedstock has several potential benefits, given optimal technological facilities. Algae secrete an array of oil-related compounds that can be used to produce biodiesel, thus avoiding the technical challenges of converting lignocellulosic biomass to biofuels. They can use wastewater as a source of nutrients and waste combustion gas as a source of carbon dioxide (with benefits for bioremediation and carbon dioxide emissions mitigation). They are also expected (with added carbon dioxide) to produce a higher biomass yield per unit area than crop plants. Algae could minimise or avoid competition with food production for land and nutrient use, and using marine algae (i.e. algae that can be grown in the sea) might reduce the need for freshwater. Finally, algae are compatible with biorefineries, producing a variety of fuels and valuable co-products, such as vitamins.

3.34 However, despite these potential benefits, technological challenges regarding the use of algae as feedstocks do exist. For example, in the UK, algal growth is likely to be limited by temperature and hours of sun for cultivation systems that rely on natural light, such as open

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[332] BP, responding to the Working Party's consultation.
[333] Sally Gee, Manchester Institute of Innovation Research, responding to the Working Party's consultation.
[334] Prof Keith Smith, responding to the Working Party's consultation.
[335] Society for General Microbiology, responding to the Working Party's consultation.
[336] For example, Shell and HR BioPetroleum – a renewable energy technology company based in Hawaii – have established the joint venture Cellana to build a demonstration facility in Hawaii for ABB: http://www.hrbp.com/News/121107.html. It was announced in January 2011 that HR BioPetroleum would become the sole owner. ExxonMobil has partnered with Synthetic Genomics Inc. – a US company interested in genomics-driven technology – to research and develop ABBs: http://www.syntheticgenomics.com/media/press/71409.html. In 2010, the US Department of Energy (DOE) awarded 24 million USD to three research consortia to address the existing difficulties in the commercialisation of ABBs. Arizona State University, University of California, San Diego, and Cellana each lead a consortium: http://www1.eere.energy.gov/biomass/news_detail.html?news_id=16122.

pond systems (discussed below). As with dedicated biofuels crops, improvements are required to make production of ABBs economically viable. Potential research targets include:[337]

- increasing the efficiency of photosynthesis to increase biomass productivity;
- increasing the growth rate;
- increasing the oil content (currently, algae can be stimulated to produce high levels of lipids using conditions of stress but this is usually at the expense of growth);
- improving the tolerance to high temperatures to reduce the expense incurred by cooling in subsequent processing stages; and
- reducing photoinhibition – a phenomenon that reduces growth rate at high light intensities, which can occur at midday in tropical zones and temperate climates.

3.35 In addition, the number and diversity of algal species available (more than 60,000 estimated) presents both an advantage and a problem. The problem arises in that there is still a lack of detailed characterisation of many algal species, for example the factors required for optimal growth or the biochemical pathways for oil synthesis. This presents barriers to optimising the cultivation or processing stages, which is necessary to achieve economic viability. However, such diversity can also be advantageous as it may be possible to use algal strains native to a particular location, exploiting their adaptation to local conditions, and thus enabling some optimisation of growth rates. The company PetroAlgae based in Florida claims to have been able to bring down costs and to scale up production of an ABB in a sustainable way simply by choosing the optimum algal subspecies.[338]

3.36 Classical breeding approaches are being pursued using genetically diverse parent strains to expand the gene pools in the breeding populations, with the hope of producing algal varieties with improved biofuel properties. There is also the possibility of improving algal species by advanced breeding and genetic modification, making use of genetic and metabolic engineering as well as synthetic biology. For example, scientists have genetically modified algae that continuously secrete oils through their cell walls.[339] The oils float to the surface of the pond, where they can be easily collected and turned into biodiesel; this facilitates large-scale industrial production. If commercially scalable, this could bypass the processes usually required for algal oil extraction and thus eliminate a costly process (which is described below). Oil extraction could also be aided by genetic modification of biological traits that influence extraction efficiency, such as cell wall strength. In terms of the technologies required for this, the same principles apply as in crops.

Algal cultivation

3.37 Algal cultivation involves the growth of algal biomass. Like lignocellulosic processing, algal cultivation has several challenges to overcome in order to produce biofuels economically; these challenges are in maximising yield and conformity of products, as well as in harvesting and extraction of the biofuel. Algal cultivation systems require water, carbon dioxide and nutrient sources, and light and space in which to exist, as well as stable temperatures within the range 20–30 degrees Celsius.[340] The choice of algal species determines the conditions required for cultivation. Currently, the most common microalgal cultivation systems are open pond systems

[337] Chisti Y (2007) Biodiesel from microalgae *Biotechnology Advances* **25**: 294–306.
[338] Personal communication, Andrew Beck, then Vice President of Public Affairs, PetroAlgae, Florida, US (November 2009).
[339] Synthetic Genomics Inc. (2009) *Next generation fuels and chemicals*, available at: http://www.syntheticgenomics.com/what/renewablefuels.html#1. This research was backed recently by the oil company ExxonMobil to scale up the process.
[340] Chisti Y (2007) Biodiesel from microalgae *Biotechnology Advances* **25**: 294–306.

and closed photobioreactors (PBRs). Both of these have some limitations. Cheaper open pond systems are vulnerable to contamination, loss of water and carbon dioxide, lack of natural light and temperature fluctuations, all of which can lower biomass productivity and growth. Closed PBRs allow greater control of conditions with better productivity, but are very expensive, and the problem of sufficient exposure to sunlight can still exist (some systems make use of artificial lighting). Currently, hybrid systems are being investigated which could combine the benefits while avoiding the problems of open and closed systems. Another strategy which integrates cultivation with treatment of wastewater is also under development. If these strategies for algal cultivation are successful, they could enable the production of significant volumes of ABBs at a reasonable cost; however, several hurdles have to be overcome first, many of which arise with scaling up to commercial operations. For example, although nutrient source management and water management are feasible at small scales, both technical and economic challenges occur at commercial scales.[341] In addition, little is known about artificial pond ecology or pathology, and such knowledge is important to develop risk mitigation/remediation strategies for large-scale cultivation.[342] Culture stability for commercial-scale algal cultivation is also an issue.[343] In sum, there is a lot of potential in advancing the production of ABBs, and this should not be discarded lightly. However, at this early stage of development it is too early to estimate whether efforts will be successful, or which of the strategies has the greatest potential for success.

Algal biomass harvesting and processing

3.38 There are two different routes to produce algal biofuels (see Box 3.4). Using algal oils produces algal biodiesel which is similar in chemical and physical properties to diesel derived from fossil oil and which compares well with the international biodiesel standard for biodiesel use in vehicles.[344] In comparison with diesel, algal biodiesel is non-toxic and has reduced levels of particulates, carbon monoxide, soot, hydrocarbons and sulphur oxides. It is also cited as being more suitable for aviation use than first generation biodiesel, having a low freezing point and high energy density. Processing all the algal biomass is similar to lignocellulosic processing and results in the same end-products. Again, it is too early to select the best route, and the most successful and economic way of processing algae into fuel will most probably be to use several methods in conjunction.

Box 3.4: Algal harvesting and processing

Algal harvesting

After cultivation, the algal biomass is harvested to allow isolation of the products. The solution containing the algal cells has to be concentrated to solutions that are 20–100 per cent more concentrated than the starting material.[345] A number of harvesting techniques are currently in use, including sedimentation in a gravity field, centrifugation, flotation and filtration.[346] However, it is likely that a combination of these approaches will be required.

Algal processing

There are two different routes for biofuels production from algal biomass: one makes use of the algal oils, which must first be extracted from the biomass; the other makes use of all the algal biomass.

Algal oils

There are two main methods for extraction of algal oils: drying the biomass and treatment with solvents to extract the products; and cell disruption to release the contents. The advantage of drying the biomass is that higher lipid yields can be obtained owing to the better access of the solvents to this dried matter. However, the high energy costs associated with drying are likely to be prohibitive when the process is scaled up for biofuels production. Cell rupture techniques avoid the need for solvents but to date this has not been done on a large scale. Oil extraction can be a costly process. Furthermore, the composition of extracted algal oils makes them susceptible to oxidation when stored, and this can limit

[341] US Department of Energy (2010) *National algal biofuels technology roadmap*, available at: http://www1.eere.energy.gov/biomass/pdfs/algal_biofuels_roadmap.pdf, p31.
[342] Ibid.
[343] Ibid.
[344] Brennan L and Owende P (2010) Biofuels from microalgae: a review of technologies for production, processing, and extractions of biofuels and co-products *Renewable and Sustainable Energy Reviews* **14**: 557–77.
[345] Greenwell HC, Laurens LML, Shields RJ, Lovitt RW and Flynn KJ (2010) Placing microalgae on the biofuels priority list: a review of the technological challenges *Journal of the Royal Society Interface* **7**: 703–26.
[346] Ibid.

their use.[347] Once extracted, the algal oils are converted into biodiesel using standard procedures as described in Chapter 2.

Algal biomass

Biochemical processes and thermochemical methods (comparable to those used in lignocellulosic processing as described above) are also used to convert algal biomass into liquid fuels.[348] Thermochemical liquefaction affords the advantage of being able to break down wet algal biomass into materials with higher energy densities. Results have already shown that it is a viable option for the conversion of algal biomass to liquid fuel. For pyrolysis, there is a great deal of promising research. Bio-oils produced by this method from algal biomass are of a higher quality than those extracted from lignocellulosic materials. However, technical challenges exist as the pyrolysis oils contain unwanted agents and are unstable and viscous.

Algal biomass could also potentially be fed into anaerobic digestion (AD) or fermentation plants. AD (digestion in the absence of oxygen) converts biomass to a methane-rich gas and is appropriate for matter with high moisture content and thus suitable for wet algal biomass. By some estimates, this approach could recover the equivalent amount of energy as extracting the algal oils, while having biomass left over that could be recycled in further algal growth cycles. Technical challenges exist in that the composition of microalgae, such as high protein content, can affect the efficiency of AD. Standard fermentation, i.e. the conversion of sugars, starch and cellulose to alcohol, could make use of the starch present in microalgal biomass. This process has also been regarded as a conversion pathway for the residual biomass after algal oil extraction.

Co-products of algal-based biofuels production

3.39 Algal oils represent just one of potentially many products that can be derived from algae and have market value. Algal biomass can contain significant amounts of proteins, carbohydrates and other nutrients, such that residues left over after oil extraction could be used as animal feed. The residues could also be used to produce biogas via anaerobic digestion, which could be used to power the ABBs production facility with excess gas/power being sold. Alternatively, the residues could undergo biochemical conversion to bioethanol/biobutanol, or thermochemical conversion and chemical catalysis to synthetic fuels for transport. Depending on the microalgae used, production of other products such as omega-3 fatty acids can be achieved. The nature of co-products available depends on whether only the algal oils or the whole algal biomass is used to produce ABBs. Making use of any component with market value (the biorefinery approach, described below) could help drive down the cost of producing ABBs.

Estimated time frame to commercialisation

3.40 Despite significant enthusiasm for ABBs production, their stage of development is even less mature than that of lignocellulosic biofuels. Some have said that the potential of ABBs has been “greatly exaggerated”.[349] In contrast to this, several companies interviewed by Accenture estimate that they will have commercial production in place by 2014. However, owing to the technological challenges of establishing the most cost-effective processing pathway for scaling up production and lowering costs, Accenture estimates that it will probably take longer than five years. Respondents to the Working Party’s consultation and the members of industry who were interviewed as part of the Working Party’s evidence gathering were more divided regarding the expected time frame for commercialisation of ABBs than regarding lignocellulosic biofuels.

> **“Some [biochemical conversion routes for lignocellulosis] are likely to be commercialised in the next year or so, and be economic by about 2013/2014. Commercialisation of algal biofuels is likely to take longer.”**[350]

[347] Brennan L and Owende P (2010) Biofuels from microalgae: A review of technologies for production, processing, and extractions of biofuels and co-products *Renewable and Sustainable Energy Reviews* **14**: 557–77.

[348] Reviewed by Brennan L and Owende P (2010) Biofuels from microalgae: a review of technologies for production, processing, and extractions of biofuels and co-products *Renewable and Sustainable Energy Reviews* **14**: 557–77.

[349] van Beilen JB (2010) Why microalgal biofuels won’t save the internal combustion machine *Biofuels, Bioproducts & Biorefining* **4**: 41–52.

[350] Biotechnology and Biological Sciences Research Council Sustainable Bioenergy Centre (BSBEC), responding to the Working Party’s consultation.

"Algae, including freshwater algae…seems to hold considerable promise, and could be commercialized within a few years."[351]

"General reading also indicates that several large international companies are investing heavily in algal sources. 10-year timescale for commercial sources?"[352]

"…research into advanced liquid biofuels from algae is at a very preliminary stage and the timeframe for implementation could be measured in decades, rather than years."[353]

"By 2030, ABBs will account for 6 per cent of diesel and 12 per cent of aviation fuel worldwide."[354]

"Cellana estimates that commercial production from its pilot project could be within four to five years from now."[355]

Jatropha

3.41 Jatropha has recently gained a lot of attention as another biofuels feedstock. Jatropha is a perennial shrub that originated in Central America and is now widespread in the tropics and neighbouring regions. Besides biofuels, it has many different uses (e.g. jatropha plantings to act as hedges to keep out livestock, and medicinal or veterinary use). Jatropha has a high oil seed content and its oil can be processed using the technology common to established biofuels production (i.e. biodiesel production from palm or rapeseed oil; see Chapter 2). Jatropha has been dubbed a ''wonder shrub' and is considered attractive for more tropical regions; there is currently much activity in South-East Asia, southern Africa, and South and Central America.

3.42 Interest in jatropha grew mainly because it is a non-food crop that in principle can grow in semi-arid areas on marginal and saline land.[356] On this basis, jatropha cultivation for biofuels production has been promoted as it would not, it has been claimed, compete with food crops. Use of jatropha as a biofuels feedstock has several advantages. It grows fast and it could, through varietal improvement and using good farming practices, produce high levels of oil per unit area in subhumid and subtropical environments (investment into plant breeding has already grown). In addition, jatropha oil has chemical and physical properties that make it suitable for processing into biodiesel; but, even without processing, jatropha oil can be used directly in certain diesel engines, lamps and cooking stoves. By-products of jatropha cultivation also have value; for example the seed cake from non-toxic varieties (toxic and non-toxic varieties exist) can be used for animal feed, and fruit shells and seed husks can be burned or used to produce biogas.

3.43 However, use of jatropha as a biofuels feedstock is faced with several techno-economic challenges.[357] Although jatropha can grow in inhospitable environments, to produce good yields it requires sufficient amounts of water and nutrients. Jatropha can also vary in yield, oil content and quality, and it can take between three and five years for jatropha to reach economic maturity. Harvesting is labour-intensive and mechanisation is difficult owing to variation in when seeds develop. Jatropha oil is also less suitable for direct use as a diesel substitute in cooler climates owing to its viscosity. If toxic varieties of jatropha are used, the use of by-products such as seed cake for animal feed is prevented, thus eliminating the additional value of the by-products. In addition, although knowledge is improving, relatively little is known about how to improve yields since jatropha does not have a long history of cultivation. Varieties that are high-yielding have not yet been identified and there is lack of understanding about how to use agronomic practices to produce high yields.

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351 Jeffrey A McNeely, responding to the Working Party's consultation.
352 Professor Keith Smith, responding to the Working Party's consultation.
353 Society for General Microbiology, responding to the Working Party's consultation.
354 Fact-finding meeting with members of industry, 2 March 2010.
355 Ibid.
356 For a review of jatropha's strengths, see: Food and Agriculture Organization of the United Nations (2010) *Jatropha: a smallholder bioenergy crop – the potential for pro-poor development*, available at: http://www.fao.org/docrep/012/i1219e/i1219e.pdf, p24.
357 Ibid, p25.

3.44 However, several of these difficulties could be addressed by advances in biology. For example, toxicity could be decreased by genetic modification and/or APBSs, and the crop could also be altered to fit mechanical cultivation, thus decreasing the requirement for human labour and increasing economic viability. The jatropha genome sequence has been reported[358] and this could represent a very important step in identifying trait genes and molecular markers for the future development of improved versions of jatropha.

Biorefineries

3.45 For all the feedstocks discussed above, the final part of the processing route in biofuels production includes steps to refine the fuel product. This can be done in a biorefinery – a system similar to an oil refinery which is used to produce fuels and useful chemicals from biomass.[359] A biorefinery can be either a transformed oil refinery or a newly built facility. Potentially, it would be possible to integrate all steps in the processing of biofuels within one facility, particularly if a range of biomass feedstocks could be converted using the same strategy.

3.46 A biorefinery aims to optimise the use of resources and to minimise waste so that the benefits and profitability of a biofuels supply chain are maximised. Thus, biorefineries integrate biofuels production with production of chemicals and energy, which are co-products and can also have market value, for example algae produce vitamins as a co-product. The co-products differ depending on which feedstocks are processed and how; however, their production may be important to both the economic viability and environmental sustainability of biofuels production. With current biofuels, typical examples of valuable co-products are the use of plant remains after fuel extraction as animal feed and the use of sugar cane bagasse to produce energy. New biofuels production affords several other potential avenues for producing valuable co-products.

3.47 Biorefineries will ideally be designed to be modular in nature so that they are able to make use of a wide range of feedstocks and adapt to changes in demand for certain chemicals, should these change. For the UK, the feasibility of two major types – that could be deployed by 2020–2025 – has been considered.[360] These include a relatively small whole-crop biorefinery complex producing a single biofuel type and several high-value co-products (including chemicals such as lactic acid) and a larger, two-platform biorefinery complex producing two types of fuels and various co-products from mixed biomass feedstocks. Already, there is a sugar beet biorefinery at Wissington, Norfolk.[361]

3.48 Future research might focus on controlling the portfolio of co-products, optimising their production and characteristics for end use. Work is also continuing to optimise the flow of materials and energy between different production units.[362] However, if biofuels production is the primary goal then co-product generation will be limited by necessity. With regard to environmental sustainability, biorefineries could employ energy recycling to reduce energy use, and carbon-sequestering processes to reduce GHG emissions. A biorefinery that sequesters

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[358] In 2009, Synthetic Genomics Inc. and the Asiatic Centre for Genome Technology announced the completion of a first draft of the jatropha genome, see: http://www.syntheticgenomics.com/media/press/52009.html. More recently, in 2010 Life Technologies and SG Biofuels reported that they had sequenced the genome to a greater confidence, see: http://www.lifetechnologies.com/news-gallery/press-releases/2010/life-techologies-ad-sg-biofuels-complete-sequece-of-jatropha-geo.html.

[359] For a review on biorefineries, including types, future directions and technical challenges, see: Fernando S, Adhikari S, Chandrapal C and Murali N (2006) Biorefineries: current status, challenges, and future directions *Energy & Fuels* **20**: 1727–37; Cherubini F, Jungmeier G, Wellisch M *et al.* (2009) Toward a common classification approach for biorefinery systems *Biofuels, Bioproducts & Biorefining* **3**: 534–46.

[360] Tamutech Consultancy (2007) *Mapping the development of UK biorefinery complexes (NFC 07/008): a report prepared for the National Non-Food Crops Centre* (London: NNFCC), pp17–32.

[361] IEA Bioenergy (2011) *Task 42 Biorefinery: database*, available at: http://www.iea-bioenergy.task42-biorefineries.com/nc/biorefinery-database/pf-single-view/?tx_powermailfrontend_pi1[show]=35&cHash=b557ce78562d926a4d440494dc6b33f7.

[362] Octave S and Thomas D (2009) Biorefinery: toward an industrial metabolism *Biochimie* **91**: 659–64.

some or all of its carbon dioxide emissions might result in a biofuels supply chain with a negative GHG metric overall, obviously also depending on the feedstock and land use impacts.

3.49 In sum, well-designed integrated biorefining appears to be a particularly promising way forward. Currently, industry is moving along the lines of extracting every drop out of the biomass in the same way that every drop is extracted out of crude oil. The initial driver for this was economic but the positive impact on energy output and GHG emissions has been recognised.

New approaches to biofuels: the promise and the problems

3.50 These examples of new approaches to biofuels illustrate the significant potential for improvement in the field and the options available to avoid the problems of the current generation, in particular regarding land use, environmental impacts and competition with food crops. However, in order to reap such benefits, several technology bottlenecks need to be overcome, and costs need to be reduced, in particular with regard to processing. Most of the technology discussed in this chapter is at the development stage and prohibitively expensive. Hence, in addition to various feedstock improvements and advances in processing and integrated biorefining, it is important that technologies are supported which have potential to be implemented at a large scale in a cost–effective way.

3.51 Chapter 4 presents an ethical framework and Ethical Principles that should be satisfied by all current and new biofuels development and production. Later chapters examine the interaction between policy and technology development, which can have important impacts on the direction of the development of new approaches to biofuels.

Chapter 4

Ethical framework

Chapter 4 – Ethical framework

Box 4.1: Overview

A number of overlapping moral values form the basis of an ethical framework that can inform society's approach towards biofuels. These are: rights and global justice; solidarity and the common good; and stewardship, sustainability and intergenerational equity.

From these values we derive six Ethical Principles which can be used to evaluate biofuels development and guide policy making. These Principles are as follows:

i. Biofuels development should not be at the expense of people's essential rights (including access to sufficient food and water, health rights, work rights and land entitlements).

ii. Biofuels should be environmentally sustainable.

iii. Biofuels should contribute to a net reduction of total greenhouse gas emissions and not exacerbate global climate change.

iv. Biofuels should develop in accordance with trade principles that are fair and recognise the rights of people to just reward (including labour rights and intellectual property rights).

v. Costs and benefits of biofuels should be distributed in an equitable way.

We then consider whether there may in some cases be a duty to develop biofuels. To address this we propose a sixth Principle:

vi. If the first five Principles are respected and if biofuels can play a crucial role in mitigating dangerous climate change then, depending on additional key considerations, there is a duty to develop such biofuels.

These additional key considerations are: absolute cost; alternative energy sources; opportunity costs; the existing degree of uncertainty; irreversibility; degree of participation; and the overarching notion of proportionate governance.

We believe that these Ethical Principles should guide any policy making in the field of biofuels – and indeed, they should be applied to comparable other technologies. As for their application, we urge policy makers and other stakeholders to use the Ethical Principles as a benchmark when evaluating technology and policy development and to make sure that serious consideration has been given to relevant aspects before proceeding. Any such decisions will be difficult under given circumstances of uncertainty, and should be made in a procedurally fair way – one that is transparent and includes all relevant stakeholders. There are also considerations of feasibility. A comprehensive ethical appraisal of biofuels technologies and policies needs to consider the ethical framework in the light of what is practical.

Introduction

4.1 The science of new biofuels is still emerging and, while there has been some debate about the harmful consequences of current biofuels production, there has been little systematic ethical inquiry. This applies in particular to the new approaches.[363] Scientists and ethicists alike are still exploring possibilities in an area fraught with unknown, or at least uncertain, variables.

4.2 Establishing a robust ethical framework for critical discussion is especially important when trying to assess the merits of new approaches to biofuels and their potential impact on the ethical problems of earlier developments. It is also important to establish whether these pathways are technically, commercially and indeed politically feasible. However, such a framework is also necessary to evaluate current and established biofuels production, which will continue to exist for the foreseeable future (see Chapter 1).

[363] An exception is: UNESCO (2009) *The ethics of adoption and development of algae-based biofuels*, available at: http://www.unescobkk.org/fileadmin/user_upload/shs/Energyethics/ECCAPWG9Algaev2.pdf.

4.3 Current biofuels (most of which belong to the so-called first generation) give rise to a number of social and ethical concerns (discussed in Chapter 2), and the new approaches to biofuels development and production (which are the subject of Chapter 3) are also likely to be controversial. In view of the multi-faceted issues associated with biofuels production, and given the extent of reasonable disagreement in modern liberal democratic societies, we sought to outline principles that might enjoy what John Rawls terms "an overlapping consensus", i.e. a consensus on a set of values, concepts and principles, even if there is disagreement on the best justification of those values and principles. People can agree on what should be done even though they do so for different reasons, each appealing to their own basic ethical values.[364] In considering current and new biofuels, which play across an international stage, a broad overlapping consensus is particularly important to encompass the many global actors involved.

4.4 This chapter proposes a number of moral values for considering both current and new biofuels. Justice- and human rights-based frameworks are invoked, alongside values drawn from social ethics, including stewardship, solidarity and the common good.[365] The values that we consider here contain elements that can overlap, and they can, in certain circumstances, have different implications. We will look therefore for practical principles which can be applied clearly in each case, and which we have drawn from one or several of the values. This report thereby offers an ethical framework which, rather than endorsing a particular course of action or technology pathway, can be used to help others to come to decisions about which path to pursue, and which can be employed to ask the right questions during this decision-making process.

4.5 When deliberating about which path to take, there may be cases where biofuels meet the Ethical Principles but in which there are difficult trade-offs. There may also be reasonable disagreements, for example about whether some benefits generated are worth the costs incurred. Where there are such difficult choices, and reasonable disagreements, it is important that the decision whether to invest in biofuels honours principles of 'procedural justice'. Procedural justice can be contrasted with distributive justice. Whereas distributive justice, as captured in Principle 5, is concerned with the fair distribution of burdens and benefits, procedural justice is concerned not with what distribution of burdens and benefits is chosen but with the process by which the political decisions are made and who makes the decision (i.e. who is included in the decision-making process). Procedural justice requires that, where people's fundamental interests are profoundly and involuntarily shaped by a political decision, those whose key interests are affected in this way are entitled – as a matter of procedural justice – to have an input into the decision-making process.[366] At the very least, the responsible use of political power requires taking into account the interests and well-being of those affected, even if those affected do not have formal standing in the decision process. A consultative process that includes companies and affected populations in developing countries could help to elucidate those interests. Or, in the UK context, the process might involve consultation with local communities affected by the situating of a new biofuels plant.

4.6 Finally, as well as considering biofuels against the alternative uses for land, they must be considered against the full range of alternative energy technologies, not just fossil fuels. While it is not the aim in this report to undertake such an extensive assessment of all energy technologies compared against each other, we believe that the ethical framework laid out in this chapter can be applied to all other technologies, and we urge policy makers to do so. This is taken up briefly in Chapter 6.

364 Rawls J (1993) *Political liberalism* (New York: Columbia University Press), Lecture IV.

365 Others might also refer to welfare-based frameworks, which we do not consider in any detail here.

366 Goodin RE (2008) *Innovating democracy: democratic theory and practice after the deliberative turn* (Oxford: Oxford University Press), chapter 7; Pogge T (2008) *World poverty and human rights: cosmopolitan responsibilities and reforms*, 2nd Edition (Cambridge: Polity Press), p190; Held D (2004) *Global covenant: the social democratic alternative to the Washington Consensus* (Cambridge: Polity Press), p100.

Moral values

4.7 The case studies in Chapter 2 highlight the complex nature of the issues raised by biofuels production, including the international impact of biofuels production and the uncertainty surrounding their attendant benefits and burdens. To address this complexity, the ethical framework developed in this chapter starts by identifying some relevant moral values. These provide the framework and moral vocabulary from which we develop six Principles. They are key moral values which are both commonly shared and of relevance to present and future biofuels. In selecting them, we are keen to highlight that they have areas of confluence addressing what we believe are the most important ethical challenges in this area. Together and through this confluence, they constitute a moral framework that enables us to construct strong Ethical Principles which should enjoy widespread support.

Human rights

4.8 When considering the moral standards against which to test biofuels, some will appeal to a set of human rights, derived from the dignity and moral status of human beings. These are, for example, reflected in the Universal Declaration of Human Rights (UDHR)[367] and in the European Convention on Human Rights.[368] There are a number of different considerations which provide support for human rights. First, there are powerful 'deontological' or principled arguments for human rights. These appeal to the Kantian ideal that people should treat all others with respect and never merely as means to an end, and they argue that a morality of human rights is needed to show proper respect for people's moral status and dignity.[369] In addition to this, there are also powerful 'teleological' or consequential arguments for human rights. These focus on the way that rights protect vital interests. From a teleological perspective, human rights provide the necessary basis for each person to attain a decent standard of living.[370]

4.9 We take international human rights as establishing a moral minimum below which the treatment of people should not fall.[371] This holds particularly for those human rights which are essential conditions for at least a decent opportunity for human flourishing. These can be seen as "negative rights",[372] which oblige others to refrain from acting in ways that arbitrarily threaten their life, impose serious threats to their health and well-being, or undermine their ability to subsist.[373] Human rights thus lead to constraints[374] which may not be crossed and which apply universally. This is particularly relevant to Principle 1 as described below at paragraph 4.27ff. (For some authors, human rights entail both negative duties to refrain from harming others and positive duties to protect others from human rights violations.[375] We affirm positive rights but in relation to biofuels (especially in Principle 1), our analysis depends primarily on the importance of negative duties not to violate the rights of others.)

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367 Universal Declaration of Human Rights of 1948.

368 European Convention on Human Rights of 1966. The European Convention on Human Rights sets out a number of rights, for example those to: freedom from slavery; life and liberty; protection of property; privacy; and freedom from discrimination. UDHR also includes the right to work and to health (including access to food).

369 Kamm FM(2007) *Intricate ethics: rights, responsibilities and permissible harm* (Oxford : Oxford University Press); Nagel T (1995) Personal rights and public space *Philosophy and Public Affairs* **24:** 83–107.

370 Buchanan A (2004) *Justice, legitimacy, and self-determination: moral foundations for international law* (Oxford: Oxford University Press), p127; Caney S (2005) *Justice beyond borders: a global political theory* (Oxford: Oxford University Press), chapter 3.

371 Shue H (1996) *Basic rights: subsistence, affluence and US foreign policy*, 2nd Edition (Princeton: Princeton University Press).

372 In political philosophy, positive rights are often defined as those rights which permit or oblige action, whereas negative rights are those which permit or oblige inaction. Likewise, the notion of positive and negative rights may be applied to either liberty rights or claim rights, either permitting one to act or refrain from acting, or obliging others to act or refrain from acting; see: Hohfeld WN (1919) *Fundamental legal conceptions, as applied in judicial reasoning and other legal essays* (New Haven: Yale University Press).

373 Pogge T (2008) *World poverty and human rights: cosmopolitan responsibilities and reforms*, 2nd Edition (Cambridge: Polity).

374 The term "side constraint" has been coined by Robert Nozick; see: Nozick R (1974) *Anarchy, state and utopia* (New York: Basic Books), p29. Nozick asserts that the side-constraint view forbids the violation of moral constraints in the pursuit of a goal.

375 Shue H (1996) *Basic rights: subsistence, affluence and US foreign policy*, 2nd Edition (Princeton: Princeton University Press), chapter 2.

4.10 Few human rights are, however, absolute in the sense that interference with them is never permissible. Indeed, it is not unusual for human rights to give rise to potential conflict. Compare, for example, Article 27(2) of the UDHR, which states that: "Everyone has the right to the protection of the moral and material interests resulting from any scientific, literary or artistic production of which he is the author",[376] with Article 27(1): "Everyone has the right freely to participate in the cultural life of the community, to enjoy the arts and to share in scientific advancement and its benefits."[377] How can both rights be given equal effect? This is certainly a challenge but it does not follow that tension is inevitable or that rights are irreconcilable.[378] Rather, some rights – such as intellectual property rights – might be seen as conditional on contributing to the common good, while in other cases a human rights approach makes it incumbent on states to ensure that the exercise of rights is consistent with giving effect to other fundamental rights.[379]

4.11 Human rights are universally enjoyed by *all* human beings, no matter the state or nation to which they belong. Thus, they can be seen as capturing one universal, albeit minimal, element of the concept of global justice. They transcend state borders and must be respected equally everywhere in the world.[380] Biofuels clearly have international implications in that many companies developing them will be using land, water and labour in one country (and not necessarily their own country) that will produce fuel to be used elsewhere. At a minimum, states have a duty to respect human rights, requiring that they design regulatory frameworks to ensure that the development of biofuels does not violate human rights, giving equal weight to the human rights of citizens and non-citizens. Where tensions arise, the duty on states is to give maximum effect to the range of rights at issue, taking into account the nature and extent of the impact on people's rights and lives. No claim should disproportionately affect the human rights of another.

4.12 It can be argued, therefore, that biofuels production breaches basic human rights when it endangers local food security or displaces local populations from the land they depend on for their daily subsistence. Similarly, biofuels production may become a human rights issue when it threatens our environmental security (see Box 4.2) through the destruction or degradation of ecosystems and natural resources which are critical to the health and subsistence of people.[381]

Box 4.2: Human rights and environmental security

The many linkages between human rights and protection of the environment have long been recognised. The 1972 United Nations (UN) Conference on the Human Environment declared that "man's environment, the natural and the man-made, are essential to his well-being and to the enjoyment of basic human rights – even the right to life itself." Some of these linkages were elaborated in the 27 principles delivered in the Rio Declaration on Environment and Development that emerged from the 1992 UN Conference on Environment and Development (the 'Earth Summit') and were further considered in the 2002 report to the 58th session of the Commission on Human Rights on a joint Office of the High Commissioner for Human Rights and UN Environment Programme seminar on human rights and the environment. There is now an emerging consensus that human rights are infringed where development actions pollute water, the land or the air, or degrade ecosystems and natural resources which are important to sustain the health and well-being of people. Human rights to life, food, water and health have environmental preconditions that must not be compromised.

4.13 It should be noted that, in keeping with the idea of overlapping consensus, invoking human rights to support our Ethical Principles does not mean that we adopt an exclusively human rights-based approach to the evaluation of biofuels technology, or, as some have done, to the

376 Universal Declaration of Human Rights of 1948, art 27.
377 Ibid.
378 Brown A (2005) Socially responsible intellectual property: a solution? *SCRIPTed* **2**: 485–513.
379 Helfer LR (2003) Human rights and intellectual property: conflict or coexistence? *Minnesota Intellectual Property Review* **5:** 47–61.
380 Note that they are only one aspect of global justice, but they are an important aspect.
381 See in this context the discussion of environmental rights in: Hayward T (2005) *Constitutional environmental rights* (Oxford: Oxford University Press), chapter 2; Nickel J (1993) The human right to a safe environment: philosophical perspectives on its scope and justification *Yale Journal of International Law* **18:** 281–95.

whole field of bioethics.[382] Mainly through their legal dimension, human rights serve very well to specify some minimum moral conditions which must be met and which are set out under Principle 1, and inform Principle 2. Indeed, the legal framework offers means and tools for dealing with potential conflicts with human rights conditions.[383] However, in many cases, these conditions are also supported by other moral values. To us, such confluence serves as a particularly strong justification for a principle.

Solidarity and the common good

4.14 Biofuels production is driven by the expectation that it may contribute to ensuring energy security, mitigating climate change and supporting economic development (see Chapter 1). The concept of human rights helps us to understand how trying to achieve these benefits might harm people in unacceptable ways. Subscribing to the idea of human rights includes obligations to protect them beyond national borders. However, human rights are only one of several approaches that seek to protect individuals, particularly those who are vulnerable, or address issues of fairness. Others might be framed in terms of one's own moral duty, or in terms of more extensive duties and responsibilities *owed* to every person in modern societies that go beyond global protection of minimum human rights.[384] These, which we focus on in this section, appeal to other moral values, such as solidarity. Values such as solidarity focus more on the importance of protecting individuals as members of groups or populations. Solidarity often leads to similar prescriptions to those that flow from a commitment to rights, but it differs importantly in that it seeks to go beyond a language of 'entitlements' and emphasises a shared commitment to the good of all. Recent Nuffield Council reports have argued that more positive duties which flow from such moral values have an important, but sometimes overlooked, contribution to make to public discussion, policy and decision making.

4.15 In particular, the Council's 2009 report *Dementia* incorporated the value of solidarity, describing it as the idea that we are all 'fellow travellers' and that we have duties to support and help each other and in particular those who cannot readily support themselves.[385] A central meaning of solidarity is that individuals or groups are not left to fend for themselves in times of difficulty. The Council's 2010 report *Medical profiling and online medicine* also invoked the "intrinsic social solidarity of a national health service", whereby the consequences of health risks are shared, and the vulnerable protected, for example through provision of a certain minimum of care.[386] In the context of biofuels, the value of solidarity directs ethical attention to the most vulnerable people within societies, reminding us that we have a 'shared humanity', a 'shared life' and that those who are most vulnerable should be given special attention. For biofuels development, the value of solidarity thus requires countries or companies to ensure just reward, that benefits are shared fairly and that burdens are not laid upon the most vulnerable in society (see Principles 4 and 5). If a particular form of biofuel could only be developed at (say) the expense of vulnerable people in developing countries then, however much it might contribute to energy needs in other countries, it should not be developed. Like human rights, solidarity thus also underpins the development of moral limits to the implementation of biofuels.

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382 See the discussion in: Ashcroft R (2008) The troubled relationship between bioethics and human rights, in *Law and Bioethics*, Freeman M (Editor) (Oxford: Oxford University Press), pp31–51.

383 For example, through the concept of proportionality in giving effect to rights or interests which are in conflict with each other.

384 For a discussion of ideals of global justice that go beyond human rights, see: Caney S (2005) *Justice beyond borders: a global political theory* (Oxford: Oxford University Press), chapter 4.

385 Nuffield Council on Bioethics (2009) *Dementia: ethical issues, available at*: http://www.nuffieldbioethics.org/sites/default/files/Nuffield%20Dementia%20report%20Oct%2009.pdf. This report suggested that the high prevalence of dementia, and the fact that we all face a significant risk of developing dementia as we get older, might enable us to develop a particular sense of solidarity with each other in the context of dementia and dementia care.

386 Nuffield Council on Bioethics (2010) *Medical profiling and online medicine: the ethics of 'personalised healthcare' in a consumer age*, available at: http://www.nuffieldbioethics.org/sites/default/files/Medical%20profiling%20and%20online%20medicine%20-%20the%20ethics%20of%20%27personalised%20healthcare%27%20in%20a%20consumer%20age%20%28Web%20version%20-%20reduced%29.pdf, p53.

4.16 Solidarity is taken here to govern the relationships and obligations between populations.[387] This wide interpretation of the value has some overlap with the value of the common good[388] which goes back at least to Aristotle. He argued that a good life is oriented to goods shared with others, the common good of the larger society of which one is a part. For him, individual goods and the common good are linked, but the latter is more important.[389]

4.17 Climate change, as a challenge with global causes, effects and implications, suggests that the value of the common good as outlined in Box 4.3 is important. It is widely recognised across societies and cultures that greenhouse gas (GHG) emissions from industry and from land and forest degradation are having dangerously negative effects on the environment. If there is an emerging worldwide consensus on this then it might be possible to get agreement on minimum common social goods, encompassing food security, energy security and environmental security. These factors, along with the ecosystem services[390] that support human well-being can be seen as the minimum common social goods necessary for human life and flourishing. The value of the common good encourages both scientists and politicians to strive for effective measures, which might include biofuels, to protect these assets across societies and generations. This provides another justification for several of the Ethical Principles discussed below (in particular, Principles 2 and 3). A common good perspective also underlines the urgency of the debate about biofuels. Although there are justifiable criticisms of some of the consequences of biofuels and fears about the possible consequences of new ones, the status quo involving ever-increasing use of fossil fuels also does not accord with a common good perspective. Doing nothing amounts to doing something extremely damaging and finding other ways of securing essential energy needs might be required to realise the common good. This is reflected in our Principle 6.

Box 4.3: Features of the common good

Justifications for the value of the common good include those listed below.

- Some global issues raise ethical concerns that are not addressed adequately using individualistic ethical concepts where, for example, climate change or world peace may have a low priority compared with individual concerns and interests.
- Common good arguments require us to identify goods that we believe all, including future generations, should share equitably, whatever society they live in.
- Common good arguments thus usually assume that there is common entitlement to essential resources.
- Common good arguments might require current generations to reduce their demands for the sake of future generations. For developed countries this could mean restrictions on lifestyle; for developing countries, this could mean reducing their expectation of achieving the same lifestyle currently prevalent in developed countries.

Common good arguments do not, therefore, depend on simply balancing the interests of those living now but, as with solidarity arguments, they explicitly evoke altruism, especially among the most privileged.

387 Solidarity can also be interpreted in narrower senses, such as solidarity between particular groups sharing certain common goals.

388 The concept of the 'common good' should not be confused with the concept of the 'public good' as that term is conventionally employed in economic analysis. A 'public good' is normally defined in terms of two characteristics. First, one person's use of a public good does not reduce the amount available for others. Second, it is not possible to exclude anyone's consumption of it, save for prohibitive costs: i.e. one cannot supply it to some but not others; see: Begg D, Fischer S and Dornbusch R (2003) *Economics*, 7th Edition (Maidenhead: McGraw-Hill Education), p232. A standard example of a public good is military defence.

389 "...though it is worthwhile to attain the end [i.e. human good] merely for one man, it is finer and more godlike to attain it for a nation or for city-states." Aristotle *The Nicomachean Ethics* (Oxford: Oxford University Press), 1094b, p4.

390 Humankind benefits from a multitude of resources and processes that are supplied by natural ecosystems. Collectively, these benefits are known as ecosystem services and include products such as clean drinking water and processes such as the decomposition of wastes.

Sustainability, stewardship and intergenerational justice

4.18 Stewardship and sustainability generate obligations to those elements of the natural world that are not of immediate material benefit to people, particularly where the interests of future generations are involved. Sustainability implies the requirement to sustain some entity or value over time. Considering what it is that should be sustained, our focus here is primarily on environmental sustainability, calling for "the sustaining into the future of some aspect of the natural environment".[391] Protection of the natural world and environmental security are vital for human life, which depends on the preservation of many benefits (ecosystem services) provided by the environment.[392] It should be noted that 'environmental sustainability' and 'environmental security' can be interpreted in many ways.[393] Some take an approach which values environmental sustainability only because and to the extent that it benefits human beings (anthropocentric approach). This perspective allows trade-offs between sustainability and other human interests, for example energy security. Others take the less anthropocentric view that sustainability needs to be protected even if human interests are not involved, for example because they regard biodiversity as an intrinsic value (i.e. a value of itself).[394] We acknowledge these perspectives but believe that it is not necessary to take one of these views in order to agree on a moderate point of view which demands adherence to sustainability standards and protecting environmental security while at the same time allowing the possibility of some trade-offs between sustainability and other goals.

4.19 A second key issue inherent in the value of sustainability is a commitment to intergenerational justice and the obligations of each generation to those that follow them. A sustainable approach to biofuels development thus requires that we do not deplete the world's natural resources without regard to the legitimate interests of future generations. The concept of environmental sustainability thus leads to the idea of stewardship. Sustainability requires us to act as stewards of the natural world, with legitimate rights to use it but also with obligations to leave it in a fit state for future generations. There is thus some overlap with claims that humans – including future generations – have rights to environmental sustainability and security, and with the obligation to protect the common good.

4.20 The Nuffield Council's 2007 report *Public health: ethical issues*[395] used the concept of stewardship to argue that an important function of government is to ensure conditions that make it easy (or easier) for people to be healthy – which might entail imposing obligations or penalties on industries where self-regulation has proven ineffective.[396] We also adopt this perspective here. In the context of this report, we take stewardship to mean that governments and other stakeholders have an obligation to ensure that the natural world and its resources are sufficiently protected, both for current and for future generations. Standards of sustainability are a way to make sure such stewardship is exercised properly, because they aim to protect important ecosystem resources. We therefore conclude that stewardship can be seen as embodying the obligation to ensure that sustainability standards are adhered to.

4.21 In addition to our stewardship responsibilities in the present, we need to ask what obligations current generations owe to future generations with respect to any beneficial or harmful effects of biofuels. The World Commission on Environment and Development (also known as the

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[391] Dobson A (1998) *Justice and the environment: conceptions of environmental sustainability and theories of distributive justice* (Oxford: Oxford University Press), p41.

[392] Millennium Ecosystem Assessment (2005) *Ecosystems and human well-being: synthesis*, available at: http://www.maweb.org/documents/document.356.aspx.pdf.

[393] See the long-standing disputes between what has been called 'strong' and 'weak' sustainability: Neumayer E (2003) *Weak versus strong sustainability: exploring the limits of two opposing paradigms*, 2nd Edition (Cheltenham: Edward Elgar); Beckerman W and Pasek J (2001) *Justice, posterity, and the environment* (Oxford: Oxford University Press), pp74–7.

[394] In the latter case, a different conception of sustainability – i.e. that values biodiversity as a value of itself – is at stake.

[395] Nuffield Council on Bioethics (2007) *Public health: ethical issues*, available at: http://www.nuffieldbioethics.org/sites/default/files/Public%20health%20-%20ethical%20issues.pdf.

[396] This report argued that in areas where the state has direct regulatory power, such as implementing clean air acts, or ensuring access to unpolluted air or drinking water, or enforcing adequate working conditions, the state must recognise its stewardship responsibility.

Brundtland Commission) argued that current generations should satisfy contemporary needs but must do so in a way that does not undermine the ability of future generations to satisfy their core needs: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[397] However, this would allow us in principle to consume resources and have enjoyable lives so long as future generations have enough to cover their most basic needs. This would be contrary to the values of stewardship and the common good. Regarding this particular point, we therefore go beyond the Brundtland view and hold that current generations should also ensure that they treat their successors in the same way that they would want to be treated by preceding generations. We are thus advocating a position that is closer to 'strong' than 'weak' sustainability.[398] It would be wrong, on this account, to leave future generations with a world that we would think unjust if we inherited it from our forebears.[399] The point derived from this is that the development of biofuels cannot be adequately addressed without taking into account the legitimate claims of future generations to receive from their predecessors a world which is liveable, to enjoy certain benefits and also not to be exposed to certain harms (see Principle 2).

A note on precautionary approaches

4.22 Risks and benefits of biofuels are often discussed in terms of 'the precautionary principle' or 'a precautionary approach',[400] and in earlier Nuffield Council reports we have used the same language.[401] The idea of carefully evaluating risks and benefits case-by-case and taking account of the relative costs of consequences flowing from particular developments[402] – which could be described as a comparative or moderate version of the precautionary approach – underlies the current report. However, we do not subscribe to any particular version of the precautionary approach; in fact, the use of the term precaution is not necessarily helpful in our context, as it is often either vague or overly restrictive. We believe that, instead of trying to develop an appropriate version of the precautionary approach suited to the biofuels context, our framework for an ethical evaluation of biofuels could be more useful.

4.23 This framework goes considerably beyond any blanket approach to precaution. We suggest that the firm Ethical Principles we develop in the following sections give far more direction to policy makers and other stakeholders regarding what to do in situations of *ex ante* uncertainty than would many of the precautionary approaches alone. Whereas some precautionary approaches do little beyond stressing the need for careful analysis of the attendant risks and benefits – which we certainly endorse – the Principles provide concrete guidance about standards to be supported and actions to be avoided. In sum, the Ethical Principles which follow replace the formal and therefore unspecific criteria of many precautionary approaches with substantive and

[397] World Commission on Environment and Development (1987) *Our common future: towards sustainable development*, available at: http://www.un-documents.net/ocf-02.htm, Part 1, chapter 2,

[398] Those who endorse strong sustainability take the view that natural capital – i.e. the range of functions the natural environment provides for humans and for itself – should be afforded special protection. Weak sustainability means that natural capital is seen as capital that can be substituted by other forms of capital, especially produced capital.

[399] See: Caney S (2010) Human rights and global climate change, in *Cosmopolitanism in context: perspectives from international law and political theory*, Pierik R, Werner W (Editors) (Cambridge: Cambridge University Press), pp43–4; Rawls J (1993) *Political liberalism* (New York: Columbia University Press), p274.

[400] For instructive discussions of different interpretations of the precautionary principle, see for example: Weiner JB (2007) Precaution, in *The Oxford handbook of international environmental law*, Bodansky D, Brunnée J, Hey E (Editors) (Oxford: Oxford University Press), pp597–612; Gardiner S (2006) A core precautionary principle *Journal of Political Philosophy* **14**: 33–60; Manson N (2002) Formulating the precautionary principle *Environmental Ethics* **24**: 263–74.

[401] See: Nuffield Council on Bioethics (2004) *The use of genetically modified crops in developing countries: a follow-up Discussion Paper*, available at: http://www.nuffieldbioethics.org/sites/default/files/GM%20Crops%20Discussion%20Paper%202004.pdf; Nuffield Council on Bioethics (1999) *Genetically modified crops: the ethical and social issues*, available at: http://www.nuffieldbioethics.org/sites/default/files/GM%20crops%20-%20full%20report.pdf. See also: Tait J (2008) Risk governance of genetically modified crops: European and American perspectives, in *Global risk governance: concept and practice using the IRGC framework*, Renn O, Walker K (Editors) (Dordrecht: Springer), pp133–53.

[402] Lewens T (2008) Taking sensible precautions *Lancet* **371**: 1992–3.

firm guidance on which lines not to cross. In this way, they are consonant with some recent, well-developed precautionary approaches.[403]

Ethical biofuels: six Principles

4.24 A common theme emerges from the discussion of the moral values as laid out above: they all emphasise that there are certain moral 'red lines' which should not be crossed by biofuels production. To apply this to biofuels production, we have developed six practical Principles. The first five Principles can be used for the practical implementation of biofuels development, while the sixth provides a guideline for future developments.

4.25 It should be noted that the Ethical Principles are presented in this chapter in a strong and aspirational way, as an *ethical ideal*. We urge policy makers to use them in order to make sure that all important ethical considerations have been given their due in the decision-making process. We are aware that there might be cases in which trying to satisfy one Principle might compromise one or more other Principles. For example, furthering equitable development through promoting biofuels on a local scale in developing countries (Principle 5) could potentially come into conflict with the need to protect the environment (Principle 2), because such local production might encroach on land with high biodiversity. In such cases, it is essential that appropriate policies and regulations are developed in order to ensure that a particular technology which might have been developed specifically to avoid violating a particular Ethical Principle does not come at the cost of compromising other ones. Moreover, decision makers need to ensure that requirements of procedural justice are adhered to, i.e. that relevant stakeholders are included in the decision-making process and that decisions are made in a transparent and accountable fashion and are based on reasons which are deemed to be rational and acceptable by all parties involved.[404] In Chapters 5 and 6 we come back to this, make recommendations for the improvement of current policy, and suggest an approach to future policy which enables all Principles to be adhered to.

4.26 **We recommend that policy makers and other stakeholders use the Ethical Principles as a benchmark when evaluating biofuels technology and policy development and always make sure that serious consideration has been given to relevant aspects before proceeding.**

Principle 1: Human rights

Biofuels development should not be at the expense of people's essential rights (including access to sufficient food and water, health rights, work rights and land entitlements)

4.27 Access to a reasonable standard of living, with sufficient nutritious food and enough fresh drinking water, is widely recognised as one of the basic human rights.[405] Based on the values of solidarity and the common good, it follows that there is a particular obligation to ensure access to sufficient nutrition for vulnerable populations, in particular those in developing countries. Even if biofuels production does not contribute to food shortages in the countries where it is used, some steps in the production process may take place in developing countries and may endanger food security there, for example by replacing food crops that would have otherwise been consumed by a local population. Water pollution can occur in biofuels production and some may also need large quantities of water. In order not to violate basic human rights, and in accordance with the requirements of protecting the vulnerable, biofuels production steps should

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[403] See, for example, accounts developed by Andrew Stirling, Stephen John or Per Sandin.
[404] These are principles that most accounts of procedural justice subscribe to; see, for example, the discussion in: Cohen J (2009) *Philosophy, politics, democracy: selected essays* (Cambridge, Massachusetts: Harvard University Press).
[405] Universal Declaration of Human Rights of 1948, art 25.

be carefully evaluated for existing or potential future impacts on food security, access to water and water quality.[406] The same holds for the import of biofuels.

4.28 A similar argument can be made regarding people's health, which is essential to an adequate standard of living. This has been recognised as an important human right and can also be endorsed from the perspective of a common good. Solidarity again encourages particular attention to vulnerable populations. It follows that biofuels production should not negatively affect people's health, either through unacceptable working conditions (including inappropriately long hours, or dangerous or unsafe/unhealthy working conditions) in agriculture or processing facilities, or by polluting local land, air and water.

4.29 Finally, both respecting land entitlements and protecting against arbitrary, forceful removal from land[407] – even where a formal deed of title does not exist – have been recognised as a basic human right, and involuntary removal from land when a land title exists is an infringement of this right. Nor is it acceptable to buy land from people who lack proper information about the value of their land.[408] This is relevant to biofuels production, which is expected to take place increasingly in developing countries. A right to access to land for subsistence can be defended from a variety of different viewpoints. Both solidarity and a human rights perspective justify safeguards against populations losing the land they have lived on without adequate compensation. People have strong economic, cultural and historic ties to their land and these must be respected through just cooperation between energy companies and legitimate land holders. It is therefore wrong for members of other countries to deal with anyone other than the legitimate owners of the land and the natural resource employed in the production of biofuels.[409]

Principle 2: Environmental sustainability

Biofuels should be environmentally sustainable

4.30 We have established that there is a case for the sustainable use of natural resources, and that countries have an obligation to act as stewards in order to make sure that minimum sustainability standards are adhered to. Moreover, current generations have a responsibility to ensure that their successors have access to resources for a sufficient standard of living. This means that future generations should inherit a world with enough food and water and clean air as well as intact important ecosystem services. It follows that biofuels production should adhere to sustainability criteria governing the careful use of water, land, and other natural resources. Biofuels should not compromise environmental sustainability, cause further declines amongst the world's biodiversity and threatened species, or further degrade important natural ecosystems, such as tropical forests.

4.31 Beyond adhering to sustainability standards, it is perhaps unrealistic to require that biofuels production does not lead to *any* harm to environmental sustainability. In other words we should not demand perfection, but we should require that biofuels do better – or significantly better –

[406] Note that this principle does not necessarily assume (nor deny) a 'positive' human right to food and water. The arguments appeal to a negative right: people have a negative right that others not act in ways which deprive them of food or water. A positive human right to food is affirmed in the Universal Declaration of Human Rights of 1948, art 25, and the International Covenant on Economic, Social and Cultural Rights of 1976, art 11 (the argument here is indebted to that advanced in another context by Pogge T (2008) *World poverty and human rights: cosmopolitan responsibilities and reforms*, 2nd Edition (Cambridge: Polity)).

[407] Universal Declaration of Human Rights of 1948, art 17.

[408] C169 Indigenous and Tribal Peoples Convention 1989 (International Labour Organization), art 14–19.

[409] The suggestion here is in part prompted by: United Nations (2009) *Kimberley Process Certification Scheme*, available at: http://www.kimberleyprocess.com/documents/basic_core_documents_en.html (concerning the conditions for just acquisition of diamonds). See also Thomas Pogge's discussion of the 'resource privilege' in: Pogge T (2008) *World poverty and human rights: cosmopolitan responsibilities and reforms*, 2nd Edition (Cambridge: Polity), pp118–121; and Leif Wenar's discussion in: Wenar L (2008) Property rights and the resource curse *Philosophy & Public Affairs* **36**: 2–32.

than fossil fuels with respect to environmental protection, and that they respect sustainability standards.

4.32 In light of these recommendations, we recognise the need to consider the adoption of genetic modification techniques where these can contribute to sustainable biofuels developments that meet the Principles proposed in this report. Current concerns about food security and environmental protection are prompting a global reassessment of the role of genetically modified crops in contributing to minimising land use and to food security in all food production systems, not just those of developing countries (see discussion in the next chapter). We also acknowledge the need to ensure that the regulatory systems in place for all crops are sufficient to ensure the sustainability of agricultural and environmental systems.

Principle 3: Climate change

Biofuels should contribute to a net reduction of total greenhouse gas emissions and not exacerbate global climate change

4.33 Man-made climate change already imposes and will increasingly impose great harms on many people, in particular those most disadvantaged. It leads to loss of life (through starvation, flooding and severe weather events) and threats to health (through water-borne and vector-borne diseases and heat stress), and undermines access to food and water.[410] Where there is loss of livelihood and of living space/territory because land is no longer habitable owing to climate change effects, this could lead to irreversible loss.

4.34 All the moral values developed above underpin the need to alleviate climate change:

- the human rights and global justice perspective, because climate change threatens the livelihood, subsistence, health and well-being of populations, in particular in the developing world;[411]
- solidarity and the common good, because as a global phenomenon with potentially disastrous consequences for the whole world, climate change affects the interests of all of humankind, and there is a particular obligation to protect vulnerable populations from its negative effects; and
- sustainability and stewardship, because climate change endangers many of the world's natural resources and may threaten life on the planet for future generations.

4.35 The case for climate change mitigation within this framework is strong, and this carries over to the evaluation of biofuels. There is a 'negative' requirement not to harm people through climate change effects by consuming energy via the introduction of biofuels.[412] Hence, a biofuels technology is only acceptable if it does not exacerbate climate change, for example as determined by GHG emissions. The common good perspective, moreover, calls for more demanding results: biofuels should lead to net GHG emissions savings.

4.36 The previous three Principles have all concerned potential harms to populations or ecosystems through the production of biofuels, and justify implementing protective measures. In this way,

[410] Intergovernmental Panel on Climate Change (2007) *Climate change 2007: synthesis report*, available at: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf.

[411] For an account of how climate change jeopardises human rights to life, health, food and water, see: Caney S (2009) Climate change, human rights and moral thresholds, in *Human rights and climate change*, Humphreys S (Editor) (Cambridge: Cambridge University Press), pp69–90. See also: Office of the High Commissioner for Human Rights (2009) *Report of the Office of the United Nations High Commissioner for Human Rights on the relationship between climate change and human rights* (A/HRC/10/61), available at: http://daccess-dds-ny.un.org/doc/UNDOC/GEN/G09/103/44/PDF/G0910344.pdf?OpenElement.

[412] Obviously, climate change effects are time-delayed: effects of today's activity impact decades later. Therefore, GHG emissions are taken as a representation of how harmful a technology is to the climate.

they embody 'negative' elements – i.e. they protect individuals or communities against being harmed or deprived of a vital good. In some cases they could thus prohibit certain activities. However, biofuels – in particular the new approaches – are expected to generate significant benefits. These may come in many different forms (e.g. financial benefits or benefits related to climate change, energy security or development), accrue along different timescales (long term or short term) and be relevant to many different stakeholders, ranging from individuals to populations and from companies to countries. The following two Principles both consider the kind of benefits that biofuels may yield, and thus include 'positive' elements – i.e. claims to some of these benefits. They differ, however, in their focus. Principle 4 focuses on the treatment of those involved in the production of biofuels, and Principle 5 focuses on sharing of benefits with others who are not necessarily involved in the production process.

Principle 4: Just reward

Biofuels should develop in accordance with trade principles that are fair and recognise the rights of people to just reward (including labour rights and intellectual property rights)

4.37 An important aspect of biofuels is the reward that accrues to people in their production. In considering the permissibility of biofuels, it is necessary to establish that those involved with the production of biofuels are not denied a just reward. This is relevant in two areas: just compensation for work; and, particularly for the new approaches, intellectual property rights (IPRs).[413]

4.38 Article 23.3 of the UDHR requires that everyone who works has the right to just and favourable remuneration, ensuring an existence worthy of human dignity.[414] Appropriate remuneration for work has become one of the undisputed standards of modern work life and is, for example, encapsulated in standards of fair trade.[415] Solidarity, as a value governing the relations between populations, also emphasises that it is not acceptable to exploit the work of poor populations in developing countries for the sake of richer populations in the developed world.

4.39 These ethical values demand adequate wages for workers in biofuels production, measured, for example, by a recognised and enforceable minimum wage within a country that is set above poverty levels. Many countries have some minimum wage scheme in place and, where this is not the case, our argument strengthens the need to establish one. It should be noted that the need for appropriate remuneration holds particularly for workers in biofuels production in developing countries, where labour rights can be quite weak. There can be justified exceptions, for example where farmers grow crops for their own use.

4.40 The ownership of intellectual property is often justified on the basis of the right to property in which one has invested time, perhaps money and also knowledge. Another frequently cited aspect is reward theory, whereby the inventor is given a right to control the invention as a reward for the benefit to society of the placing of the invention into the public domain. Professor Joan Robinson has explained very well the practical dilemma embedded in all intellectual property systems, which then, in many cases, leads to ethical concerns: "The justification of the patent system is that by slowing down the diffusion of technical progress it ensures that there will be more progress to diffuse…Since it is rooted in a contradiction, there can be no such thing as an ideally beneficial patent system, and it is bound to produce negative results in particular

413 Intellectual property rights, very broadly, are rights granted to creators and owners of works that are the result of human intellectual creativity. The main intellectual property rights are: copyright, patents, trade marks, design rights, protection from passing off, and the protection of confidential information.

414 Universal Declaration of Human Rights of 1948, art 23.

415 World Fair Trade Organization (2009) *10 standards of fair trade*, available at: http://www.wfto.com/index.php?option=com_content&task=view&id=2&Itemid=14.

instances, impeding progress unnecessarily, even if its general effect is favourable on balance".[416]

4.41 The values of solidarity and common good imply that contributing towards knowledge about biofuels production can be seen as contributing to the common good of striving for climate change mitigation and energy security. If we are to find ways to lower GHG emissions while securing energy demands, we will need to advance our knowledge about suitable technologies to eventually replace those based on fossil fuels. Solidarity demands that such knowledge be shared in order to support the most vulnerable. On the other hand, companies will not be able to make the very large investments needed to convert knowledge into practical benefits unless they can be assured of a reasonable period of exclusivity in which to reap sufficient rewards. It has been argued that the disclosure of knowledge and the availability of a new product is the way this knowledge is shared and provides the benefit to society. In order to give full effect to Principle 4, it is important to recognise that while the existence of IPRs can provide a reward for innovation, it is the exercise of IPRs that can ensure the knowledge is shared and thus fully meet the requirements of Principle 4.

4.42 As another dimension, those who promote the production of biofuels are under a responsibility to exercise due care when encouraging the economically vulnerable to convert land and natural resources for use in biofuels production. In particular, it is important not to encourage extensive changes in developing countries, only to decide shortly thereafter not to purchase such biofuels, for example because of abrupt changes in policy in the developed world.

4.43 It is crucial here to develop clear, transparent and stable medium-term plans. Of course, companies in developed countries may quite reasonably change their plans and are not required to be permanently locked into an earlier policy when other more advantageous options arise. Nonetheless, this does not preclude reaching agreed medium-term arrangements that honour the reasonable expectations of the vulnerable, especially those in developing countries, while retaining some flexibility for companies investing in biofuels production.

Principle 5: Equitable costs and benefits

Costs and benefits of biofuels should be distributed in an equitable way

4.44 The potential benefits associated with future biofuels may, however, go far beyond just reward for the work and knowledge involved in the production of biofuels (Principle 4). There may be other more general benefits that can potentially be shared with a wider range of people. The values of solidarity and the common good call for the protection of the vulnerable, and a commitment to distributive justice similarly calls for the fair distribution of such benefits. If biofuels do yield benefits either to i) energy security, ii) enabling people to meet their responsibilities to mitigate climate change, iii) increased economic development/revenue/jobs, or iv) other benefits, then what is a fair way to share these benefits? Bringing in the concept of global justice, how should the benefits be distributed among members of developed countries and developing countries? We propose the following two rules:

- *(Rule 1) Symmetry between benefits and harms*: benefits should be allocated to people in proportion to the extent to which the generation of biofuels has adversely affected their interests or exposed them to risk, such as through pollution, higher food prices (where clearly attributable) or changes in landscapes and livelihoods.

- *(Rule 2) Benefit sharing to further Millennium Development Goals*:[417] the Member States of the United Nations have pledged to meet eight Millennium Development Goals. Where biofuels provide a sustainable form of transport fuel and where they bring opportunities for

[416] Robinson J (1956) *The accumulation of capital* (London: Macmillan and Company), p87.
[417] United Nations (2010) *Millennium Development Goals*, available at: http://www.un.org/millenniumgoals/.

development then – in light of the ideas of the common good and global justice – there is a case for incentivising the production of biofuels so that the production process shares the benefits in ways that further these goals.[418]

4.45 These rules are helpful in considering what benefits and burdens might arise, and how they should be distributed. Chapter 5 discusses further how they might be applied through policy, for example in public–private partnerships.

Beyond Principles 1–5: is there a duty to develop biofuels?

4.46 An ethical evaluation of any technology tends to focus on harms that the technology brings or might bring to populations or natural resources, and whether some of these harms make it unjustifiable to pursue the technology ("*first* do no harm"). This is reflected in the Ethical Principles of this framework, of which the first three are the strongest.

4.47 A biofuels technology or policy tested against Principles 1–5 could come out somewhere within a wide range. It could clearly violate one or several Principles, and thus should not be pursued. It could also violate one or several Principles, but in ways that could be amended and managed through policy. Finally, a biofuels policy or technology could satisfy all Principles. In the latter cases, a biofuels policy or technology is *morally permissible*. But might there be a duty to develop biofuels?

Principle 6: Duty?

If the first five Principles are respected and if biofuels can play a crucial role in mitigating dangerous climate change then, depending on additional key considerations, there is a duty to develop such biofuels

4.48 Once the first 'do no harm' step of the ethical evaluation has been undertaken and safeguards have been developed, it is important to consider whether there may be a duty to promote any biofuels. The benefits of biofuels production – and the need to meet certain pressing moral objectives, most notably averting dangerous climate change – may be such that it becomes a responsibility to consider the development of a technology in order to reap its benefits. The main expected benefits of biofuels production have been described in earlier chapters, and they relate to to the three main drivers: i) climate change mitigation; ii) energy security; and iii) economic, rural and/or agricultural development. As laid out in Chapter 1, and given a commitment to human rights and a common good perspective, these constitute important social goals.

4.49 In light of climate change's potentially catastrophic effects on the enjoyment of individual human rights and its violation of the ideals of the common good, we affirm that there is an ethical imperative to prevent dangerous climate change. Where a biofuels technology – whether established or one of the new approaches – can help realise the pressing need to mitigate dangerous climate change then it may be that there is a duty to promote such biofuels.

[418] It might be asked what should be done if these rules conflict. We make two recommendations here. First, one widely held conviction is that the negative duty not to harm others generally takes priority over other positive duties. Given this, then, other things being equal, the duty to compensate those adversely affected by biofuels production and to protect people from being adversely affected (rule 2) takes priority over other principles of benefit sharing. Second, however, when other things are not equal, then the other rule may take priority. If, for example, i) the disadvantages imposed on others by biofuels production are fairly slight, and ii) the benefits could be distributed in such a way that they would make a considerable contribution to the successful pursuit of Millennium Development Goals, *then* there may be a case for distributing the benefits according to rule 1 rather than rule 2.

4.50 Firstly, Ethical Principles 1–5 should be met. Secondly, whether there is such a duty depends on a number of additional key considerations. These are:

a *the absolute cost consideration*: is the cost of developing biofuels too great? Even where a biofuels technology brings benefits and enables humans to meet pressing ethical objectives, this does not lead to a duty to develop such biofuels (and for state investment in it) if the costs (which might be direct financial costs or opportunity costs) incurred are out of all proportion to the benefits generated. Such costs could entail greater harms, outweighing the benefits of biofuels. This thought does not preclude considerable financial investment, but it does insist that this can be justified only if the resulting benefits are proportionate to the cost.

b *the alternative energy sources consideration*: are there other energy technologies which can also help realise the goal of mitigating climate change and which do so more effectively (e.g. they involve greater reductions in GHG emissions for a similar or lower cost)? There are other potential energy sources for road transport (e.g. the production of hydrogen or electricity from low carbon technologies such as geothermal, solar photovoltaics, hydroelectric, tidal, wind and nuclear). There are also possibilities for increasing energy efficiency of existing energy sources for transport. Decisions about biofuels have to be taken in the light of these other options (and their merits and demerits) and what would be the best policy mix. This could effectively mean that biofuels may not be simply an alternative to other ways of achieving low carbon transport, but that they may be deployed as part of a portfolio in many countries which could also include other vectors such as electricity, hydrogen, etc.

c *the opportunity cost consideration*: might the resources used in biofuels production (such as biomass) be required in order to realise some more pressing ethical imperative, such as, for example, bioenergy to meet other fundamental needs in a climate-protecting way? Biomass may be used for heating and cooking and these needs must also be borne in mind when considering whether to develop biofuels production.

d *the uncertainty consideration*: it is important to recognise that there is likely to be great uncertainty about the technologies and any future developments, for example regarding full life cycle assessment outcomes, costs of scaling up, and social impacts. This suggests that, rather than relying on a single snapshot of the potential of technologies, their likely costs, alternative uses of biomass and alternative energy sources, it is important to review and monitor each of these factors on a continuing basis.

e *the irreversibility consideration*: it is also important to be aware of the possibility, and dangers, of setting in process irreversible policy decisions. There is, thus, a need to guard against implementing an irreversible set of commitments that involve a sub-optimal use of biomass and/or alternative energy sources. Again, this implies a need for continuing monitoring of decisions and policies.

f *the participation consideration*: while assessing whether and how these conditions apply, a commitment to procedural justice demands sufficient inclusion of relevant voices in agenda setting and policy formation. For example, those directly affected by biofuels production should be heard regarding their concerns about local impacts and potential negative side effects.

g *the overarching 'proportionate governance' consideration*: it has been shown that 'one size fits all' approaches to policy are not successful in complex areas. Instead, policy needs to be symmetrical and proportionate to the risks and benefits to individuals and society, allowing for different applications depending on the context.[419]

[419] Academy of Medical Sciences (2011) *A new pathway for the regulation and governance of health research*, available at: http://www.acmedsci.ac.uk/p99puid209.html.

4.51 Where biofuels honour the first five Principles, and where they enable society to realise its overarching duty to mitigate dangerous climate change in ways that meet the additional considerations, there is, to that extent, a duty to develop the production of biofuels.

4.52 However, this raises the question of who then would bear the duty to develop biofuels. In line with the commitment to human rights and to the ideals of solidarity and the common good, we affirm that the burden should not be borne by the least advantaged and most vulnerable, but should instead be borne according to ability to pay. Those with the greatest ability to pay should bear the lion's share of the burden. Second, and in addition to this, those who have used up a greater share of fossil fuels have a responsibility to act so that others – current and future – have alternative energy sources (including possibly biofuels) available to them. In short, the polluter should pay.[420]

4.53 Ascertaining when Principle 6 applies will require a case-by-case examination in the light of a number of practical and scientific considerations. Such a judgment is inherently complex as it must also consider issues surrounding the scale of production that is appropriate, the need to spend resources effectively and carefully, and the fact that there are both alternative ways to generate energy and alternative uses of a particular feedstock which might be more advantageous than its use as a biofuels feedstock. These issues are taken up through the discussion of current and future policy and regulation for biofuels in Chapters 5 and 6.

[420] This could be limited, as has been done with climate change policy, to the years following 1990, in order to avoid complex issues around retrospective compensation for past pollution.

Chapter 5

Ethical Principles and biofuels policy

Chapter 5 – Ethical Principles and biofuels policy

Box 5.1: Overview

This chapter explores in more detail the policies that have determined the current state of development, production and utilisation of biofuels, the policy environment within which they are embedded and their benefits and ethical implications, i.e. the 'biofuels system'.

The aim of the chapter is:

- to test existing biofuels policies (principally those relevant to the UK and the rest of the European Union) against our Ethical Principles;
- to identify deficiencies in these policies and areas where they conflict with our Ethical Principles; and
- to make recommendations for possible improvements or modifications to existing biofuels policies that help achieve compliance with our Ethical Principles.

We recognise the enormous challenges when developing policy in a multidimensional and global area of rapid development and great uncertainty. On the other hand, precisely because biofuels are driven largely by policy and regulation, it is very important to point out where existing policy violates our Ethical Principles, and how this could be avoided or ameliorated.

Where Principles are not met and decision makers find themselves 'on the wrong side' of one or several of our Principles, they will need to apply sound judgment and go as far as possible to meet the Principles in the future. The Principles, in turn, can help to identify which of the alternatives in a particular situation is the least problematic, and serve as a benchmark of what production should aspire to.

In this chapter we focus mainly on biofuels-specific policy instruments, such as the European Renewable Energy Directive. Under each of the Ethical Principles developed in the previous chapter, we investigate relevant existing policies and their contribution towards violating elements of the Principle. We also identify challenges for the future, and, towards the end of the subsections, make specific recommendations as to how existing policy could be improved.

In addition, later in the chapter we carry out the same analysis for general policy instruments, such as guidelines for research and development, trade law, land use policies and general intellectual property policies.

Our recommendations may not be the only options but they provide what we believe to be the best available way forward, and we hope that these will provide some guidance to stakeholders when developing ethical biofuels policy.

Introduction

5.1 We have so far taken a general approach and have provided an ethical framework that policy makers can apply to decisions, and in policy development. In this chapter, we work the Ethical Principles through existing policies with more technical detail. In Chapter 6, we return to more general points.

5.2 From the information given in earlier chapters, the conclusion could be drawn that a major cause of the ethical issues raised by biofuels production is not the technologies themselves, but rather the policies that led to their extremely rapid adoption. Our analysis so far has covered a complex set of interactions related to the development, production and use of biofuels and the policy environment within which they are embedded. We will refer to this as the 'biofuels system', and this chapter explores in more detail the policies that have largely determined the current state of this system; the potential of these policies to support or violate the Principles laid out in our ethical framework; and how future policy developments could improve the ethical performance of this biofuels system.

5.3 Formulating policies so that they avoid violating our Ethical Principles while enabling the generation of the expected benefits of biofuels is a difficult task in any circumstances and these problems are amplified in such a rapidly changing technological landscape. Quantitative and qualitative aspects of technological advances are difficult to predict and thus their early integration into policy formulation is problematic. For example, the extent to which it will be possible through direct incentives to promote innovation or, through other policy incentives, to improve the efficiency of biofuels production from lignocellulosic feedstocks is still uncertain and meanwhile entirely new approaches to biofuels production may emerge. At the same time, breakthroughs in other areas of energy generation may render biofuels obsolete. There is thus a dynamic interaction between technology development and policy development.

5.4 Policy decisions have to take account of the long timescales and often massive infrastructure investments involved in bringing biofuels technologies to market, creating a danger of becoming locked into a sub-optimal technology. On the other hand, spreading resources more thinly as a means to keeping a wider range of options open risks an outcome where none of them is sufficiently well supported to achieve success. The diversity of types of risk involved could lead to paralysis, with missed opportunities to make significant progress in climate change mitigation, energy security and economic development.

5.5 Many policies affect the way biofuels are developed. Biofuel-specific policies, such as biofuels targets, duties on particular biofuels or biofuels certification (the latter still being under development), play out against an important general policy background, including trade agreements, intellectual property (IP) law, land and labour rights, and other general policies that shape the conditions under which biofuels are developed and adopted. The challenge for biofuels lies in aligning these biofuel-specific and general policies with effective technology development on the one hand, and with our Ethical Principles on the other. Moreover, specific and general policies should, wherever possible, align with each other and avoid inconsistencies such as perverse incentives or contradictions.

5.6 In this chapter, we consider how the dynamic interactions between policy, technology and their pragmatic implementation can be filtered through the Ethical Principles that we proposed in Chapter 4, supporting the development of a more ethical biofuels system. We describe relevant policies and discuss examples where there is a danger that they conflict with our Ethical Principles. More specifically, this chapter aims:

- to test existing biofuels policies (principally those relevant to the UK and the rest of the European Union, EU) against our Ethical Principles;
- to identify deficiencies in these policies and areas where they conflict with or fail to meet the requirements of our Ethical Principles; and
- to make recommendations for possible improvements or modifications to existing biofuels policy in order to help achieve compliance with our Ethical Principles.

5.7 Under the heading of each of our Ethical Principles, we therefore discuss the relevant *biofuel-specific* policy instruments and investigate whether and how these policies might currently contribute to violations of the Ethical Principles or to supporting them. Where possible, we also look at continuing efforts to improve biofuel-specific policies and suggest how they could tackle future challenges. *General* policy instruments, which form a continuous background to several specific policy instruments and indeed to several of our Ethical Principles, are considered in paragraphs 5.103–5.122. In this chapter, we restrict our analysis to Principles 1–5. Issues raised by Principle 6 are taken up in Chapter 6, as are some general policy changes we recommend as part of our governance approach.

Ethical Principles and their application through policy

5.8 A major cause of the ethical issues raised by biofuels production is not the technologies themselves but rather the policies that led to their extremely rapid adoption. In this chapter, we consider how the interaction of policy, technology and their practical implementation can be filtered through the Ethical Principles (see Box 5.2), supporting the development of a more ethical biofuels system.

Box 5.2: Our Ethical Principles

i. Biofuels development should not be at the expense of people's essential rights (including access to sufficient food and water, health rights, work rights and land entitlements).

ii. Biofuels should be environmentally sustainable.

iii. Biofuels should contribute to a net reduction of total greenhouse gas emissions and not exacerbate global climate change.

iv. Biofuels should develop in accordance with trade principles that are fair and recognise the rights of people to just reward (including labour rights and intellectual property rights).

v. Costs and benefits of biofuels should be distributed in an equitable way.

vi. If the first five Principles are respected and if biofuels can play a crucial role in mitigating dangerous climate change then, depending on additional key considerations, there is a duty to develop such biofuels.

These additional key considerations are: absolute cost; alternative energy sources; opportunity costs; the existing degree of uncertainty; irreversibility; degree of participation; and the notion of proportionate governance.

5.9 While we believe that the Ethical Principles developed in Chapter 4 should be adhered to in all biofuels policy, whether existing or newly developed, we are aware of the enormous challenges when developing policy in an area of rapid development and great uncertainty. There can be many difficulties in enforcing a firm ethical framework in the real world because the reality of policy making is complex, messy, and often far from perfect. Moreover, there is also a danger of too much additional 'red tape' and bureaucratic burden. The challenge is to overcome 'one size fits all' approaches and develop policy that is proportionate to the specific risks and benefits involved.[421] But it is precisely because of the extent to which biofuels developments are driven by policy and regulation that it is important to identify where existing policy is failing to meet the required ethical standards, and how this could be avoided or ameliorated.

5.10 In this chapter we test existing biofuels policies against our Ethical Principles and develop recommendations as to how they could be improved. In doing so, we are not claiming that this is the only way to proceed. In a complex policy area, there may be other options, but we believe that our recommendations offer a way forward, and we hope that these will provide helpful guidance when developing future biofuels policy.

Principle 1: Human rights

Biofuels development should not be at the expense of people's essential rights (including access to sufficient food and water, health rights, work rights and land entitlements)

> **"Industrial biofuels…contribute to speculation on the food markets, world food price rises and world hunger. They are linked to human rights abuses and displacements of peoples from their land in South America, Asia and Africa. Society moving towards a greater use of biofuels will exacerbate all the above problems further and lead to extreme changes in weather patterns, food and water insecurity and therefore increases in climate refugees and societal unrest and possibly societal collapse even more quickly than predicted by mainstream climate scientists."**[422]

> **"By considering bans on biofuels, the world would be denying livelihood opportunities to the poor, increasing hunger. No one speaks of banning tobacco, cotton, floriculture or other non-food crops in order to free up more land for food, because these provide crucial income-earning opportunities for farmers. Biofuels do the same."**[423]

[421] Academy of Medical Sciences (2011) *A new pathway for the regulation and governance of health research*, available at: http://www.acmedsci.ac.uk/p99puid209.html.
[422] Food Not Fuel, responding to the Working Party's consultation.
[423] International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), responding to the Working Party's consultation.

Target-based biofuel-specific policies

5.11 To incentivise sustainable biofuels production that supports human rights, it is essential that appropriate new and existing technologies and their deployment are supported through policy development. This involves not only preventing bad practice, but also encouraging good practice.

5.12 In Europe, the Renewable Energy Directive (RED)[424] is of huge importance in driving and regulating the biofuels system. European law requires all EU Member States to implement this Directive into national law by the end of 2010. The RED and national policies in Members States (in the UK, this is the Renewable Transport Fuels Obligation, RTFO) set out regulatory frameworks for biofuels and introduce mandatory targets for producers. The current RED mandatory target is for 10 per cent of transport energy to come from renewable sources in Member States by 2020.[425] Such target-based policies, in particular those focusing exclusively on biofuels, have been criticised as contributing to human rights violations that take place beyond the boundaries of EU Member States, for example in developing countries. These policies effectively establish artificial markets for large-scale biofuels production with several consequences. Firstly, biofuels providers, incentivised to fulfil targets, scale up production rapidly and in the easiest way possible, often resulting in producers moving into countries with a lax regulatory environment. Indeed, a recent World Bank report stated that investors tend to target countries with lax laws when acquiring land.[426]

5.13 Secondly, biofuels markets supported and incentivised by target-based policies make it attractive for poorer countries to scale up their own biofuels production rapidly; however, in some cases this has been associated with human rights violations.[427] The most controversial example of this is the 'food versus fuel' debate (discussed in Chapter 2) where biofuels markets established as a result of specific targets were blamed for the diversion of food crops into fuel production, and this in turn was blamed for local food shortages in some developing countries and spikes in global food prices. Recent reports, for example from the World Bank,[428] have painted a more complex picture. Biofuels production is certainly not the only culprit behind rising food prices; target-based policies incentivising production are one among several factors impacting on the availability and the price of food.[429] Nevertheless, provisions need to be implemented to avoid such effects, as well as other threats to human rights, in the future.

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424 Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16.

425 In detail, the target is specified as a 10 per cent target for renewable energy content. The contribution of biofuels is included, along with those from alternative fuels and improvements in fossil fuels. The RED establishes minimum thresholds for the greenhouse gas reduction of biofuels. The Fuels Quality Directive that works alongside the RED incentivises the blending of biofuels that exceed the minimum requirement (in the Fuel Quality Directive, the overall target is now actually specified as a 10 per cent reduction in life cycle GHG emissions per unit of energy supplied: Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC [2009] OJ L140/88, art 7(a)). The UK's RTFO sets the national target at 5 per cent of biofuels by 2013. Such national target-based policies effectively establish mandatory markets for biofuels, Art 4 of The Renewable Transport Fuel Obligations Order 2007 amended by The Renewable Transport Fuel Obligations (Amendment) Order 2009.

426 World Bank (2010) *Rising global interest in farmland: can it yield sustainable and equitable benefits?*, available at: http://siteresources.worldbank.org/INTARD/Resources/ESW_Sept7_final_final.pdf, p49.

427 In 2007, Amnesty International highlighted the rescue in Brazil of more than 2,000 sugar cane workers from forced labour or conditions analogous to slavery. See: Amnesty International (2008) *Brazil: Amnesty International report 2008*, available at: https://www.amnesty.org/en/region/brazil/report-2008#. It is difficult to distinguish precisely whether these are problems of the Brazilian sugar cane industry or the Brazilian sugar cane industry as it relates to bioethanol production.

428 Baffes J and Haniotis T (2010) *Placing the 2006/08 commodity price boom into perspective*, available at: http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2010/07/21/000158349_20100721110120/Rendered/PDF/WPS5371.pdf. This paper from the World Bank argues that the effect of biofuels on food has not been as large as originally thought; instead, the use of commodities by financial investors may have been partly responsible for the 2007/08 spike.

429 Paarlberg R (2010) *Food politics: what everyone needs to know* (Oxford: Oxford University Press), chapter 3; Westhoff P (2010) *The economics of food: how feeding and fueling the planet affects food prices* (New Jersey: FT Press).

5.14 The RED has recently incorporated some social requirements. It gives a broad commitment to assessing/monitoring every two years the impacts of biofuels production on agricultural products (especially food), on wider development issues and on land use rights. If necessary, coercive action should be taken to address any shortcomings. It also supports further assessment of social consequences of the production and consumption of biofuels. In the UK, the Renewable Fuels Agency (RFA) developed some sustainability criteria, the RTFO-Meta standard, which include standards for social sustainability. However, the RTFO-Meta standard does not include any safeguards against impacts on food security.[430]

5.15 Within Europe, standards such as the RTFO-Meta standard will not be difficult to implement and enforce as they are set within a strong legal and policy framework that supports similar standards in many other areas. It is thus unlikely that Principle 1 will be violated for biofuels produced within the EU. However, the RED also proposes that equivalent compliance for biofuels sourced *outside* the EU should be achieved by multilateral and bilateral agreements and voluntary international or national schemes, such as the Conventions of the International Labour Organization.[431] These include protection against child labour and forced labour, and aim to ensure a minimum wage level, acceptable work conditions and equal pay between men and women. In the absence of concrete and binding agreements and schemes, it is proposed that EU Member States would require suitable reporting by producers and suppliers of biofuels from countries outside the EU. The form and impact of such propositions is currently unclear.

5.16 Owing to reasons of implementation, cooperation and enforcement, it is much easier successfully to implement policies that aim to ensure that human rights are not endangered on a *national* level than on an international level. As mentioned in Chapter 2, Brazil has in the past been accused of ignoring human rights issues in producing biofuels. However, recent policy developments, such as the ZAE Cana zoning policy[432] (which specifically regulates and includes provisions for protecting food security), appear to have had some positive effect. It remains to be seen whether the degree of enforcement of this policy is sufficient, but ZAE Cana zoning could be seen as one potential model of a national policy that could be used in other countries.

Challenges for the future: sustainability standards and certification

5.17 A promising international approach is emerging through sustainability initiatives that cover issues relevant to human rights as well as environmental sustainability (Principle 2) and the reduction of greenhouse gas (GHG) emissions (Principle 3). Biofuels sustainability standards lay out guidelines for environmentally and socially acceptable biofuels production and distribution. Certification is a policy instrument to signal that such standards have been satisfied by demonstrating compliance.[433] Certification can be voluntary or mandatory; currently, the RED calls for voluntary sustainability schemes to be implemented by EU Member States. Benchmarked[434] against the (itself incomplete) RTFO-Meta standard, the Roundtable on Sustainable Biofuels (RSB) standards appear currently to have the most comprehensive set of sustainability criteria (see Box 5.3). The RSB ultimately aims to operate as a certification scheme.

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[430] Renewable Fuels Agency (2010) *Benchmarks of sustainability standards and certification schemes*, available at: http://www.renewablefuelsagency.gov.uk/reportsandpublications/guidance/carbonandsustainabilityguidance/benchmarks.

[431] ILOLEX (2011) *Database of international labour standards*, available at: http://www.ilo.org/ilolex/english/convdisp1.htm.

[432] Ministério da Agricultura, Pecuária e Abastecimento (2009) *Zonamento Agroecologico de Cana-de-Acucar*, English version available at: http://www.unica.com.br/downloads/sugarcane-agroecological-zoning.pdf.

[433] An overview of current sustainability and certification initiatives can be found at: http://www.renewablefuelsagency.gov.uk/sites/rfa/files/_documents/Benchmark_results_per cent28July_2010per cent29.pdf.

[434] Renewable Fuels Agency (2010) *Benchmarks of sustainability standards and certification schemes*, available at: http://www.renewablefuelsagency.gov.uk/reportsandpublications/guidance/carbonandsustainabilityguidance/benchmarks.

Box 5.3: Roundtable on Sustainable Biofuels[435]

The Roundtable on Sustainable Biofuels (RSB) is a voluntary, international stakeholder organisation, coordinated by the Energy Center at the École Polytechnique Fédérale de Lausanne, which brings together farmers, industry, non-governmental organisations (NGOs), governments, experts and other biofuels stakeholders. It seeks to establish standards for sustainable biofuels production and a third-party certification scheme which would allow the enforcement of these standards for all biofuels awarded the label "sustainably produced".

The current RSB standard covers more aspects than most other standards, and includes the entire biofuels value chain from "farm to tank". For example, the criteria and indicators of compliance address local food security and the use of technology, which, for example, are not part of the UK RTFO-Meta Standard.

RSB sustainability criteria

The RSB standard Version 1 is based on 12 criteria under the following headings:

1 Legality
2 Planning, Monitoring and Continuous Improvement
3 Greenhouse Gas Emissions
4 Human and Labour Rights
5 Rural and Social Development
6 Local Food Security
7 Conservation
8 Soil
9 Water
10 Air
11 Use of Technology, Inputs and Management of Waste
12 Land Rights

The RSB is also developing the 'Standard for EU market access', to be used by producers, operators and traders who supply biofuels to the EU. This is intended to ensure compliance of the RSB certification system with the sustainability criteria for biofuels as defined by the RED. All participating operators producing, converting, processing or trading biomass/biofuels for use in the EU will have to comply with the provisions of the EU Standard in addition to the RSB "Principles & Criteria" and all other RSB standards to qualify for certification.

5.18 It is of course debatable whether multilateral and bilateral agreements such as those captured in the RSB standard will have enough 'bite' to avoid impacts on food and water security and to allow sufficient protection of health and land and labour rights if they remain voluntary. Several of the voluntary agreements and schemes mentioned in the RED, such as the Conventions of the International Labour Organization, have been in existence for a long time, yet breaches are still reported.[436]

Challenges for the future: technologies and scale of production

5.19 In reaction to the problems surrounding established biofuels production from food crops, the RED also seeks to encourage research on, and development and deployment of, new biomass feedstocks and biofuels technologies, some of which have been described in Chapter 3. In the RED, these are referred to as second and third generation biofuels. For example, EU Member States might give extra support for biofuels that are derived from particular non-food biomass feedstocks.

5.20 The right to food, land, water and – through these – to health can all be violated if land, water and food are used for biofuels production. Indeed some argue that we need all even remotely productive land and any available water for food production, and therefore *all* biofuels violate Principle 1. However, not *all* biofuels use these resources. Examples include the use of

[435] Roundtable on Sustainable Biofuels (2010) *RSB principles & criteria for sustainable biofuel production*, available at: http://rsb.epfl.ch/files/content/sites/rsb2/files/Biofuels/Versionper cent202/PCsper cent20V2/10-11-12per cent20RSBper cent20PCsper cent20Versionper cent202.pdf.

[436] For example, see: International Labour Organization (2009) *Information and reports on the application of conventions and recommendations: report of the Committee on the Application of Standards*, available at: http://www.ilo.org/wcmsp5/groups/public/---ed_norm/---relconf/documents/meetingdocument/wcms_108378.pdf.

agricultural or municipal residues, as described in Chapter 3. Furthermore, as mentioned above, the relationship between world food supply and hunger is complex. It is not necessarily the case that if more food is produced on the planet, fewer people will be hungry. It is possible that low-tech local biofuels production in developing countries can improve the situation by providing a local energy source without affecting local food supplies. Both the policies and the technologies needed to drive improvements in these areas differ for different parts of the world. In some cases it will be appropriate for the development of biofuels to be on a local basis to serve the needs of local farmers (small scale). It is important that policies to support technology development for small-scale local production are not neglected in the debate about large-scale production for the mass market (see also paragraphs 5.91–5.95 and recommendation 5.100).

5.21 It appears that, in order to support appropriate technology development to avoid impacts on food and other human rights, the question to ask is how the best use can be made of any particular area of land and source of local water supply so that people's basic human rights are met in a sustainable way. This, however, is very obviously a challenge that goes far beyond the context of biofuels policy making. Production of both food and biofuels crops can be increased using a range of technologies. For example, in 2009 the Royal Society suggested a number of systematic improvements to allow for sustainable intensification of agriculture (see Box 5.4), and these should be supported, but ultimately integrated policies are necessary for sustainable development of all crops, whether they are used for food or for fuel. We will come back briefly to this fundamental challenge in Chapter 6.

Box 5.4: Sustainable intensification of global agriculture

In October 2009, the Royal Society published a report[437] on the contribution of the biological sciences to sustainable intensification of global food crop production, concluding that they must play a vital role, but refraining from discussion of what policies might be needed to deliver this aspiration.

The report examined the technologies that could be used, including genetic improvement of crops and new crop and soil management practices. Genetic improvement – achieved through either breeding or genetic modification – could be used to refine existing crops. Equally, more radical improvements were possible, with potential changes including a reduced need for fertiliser or increased photosynthetic efficiency. Crop and soil management practices could be used to address constraints in existing crop varieties.

The report adopted an "inclusive approach" to these methods, asserting that a diversity of approaches is needed to meet the range of problems of global agriculture that are determined by local conditions, crops and cultures.

Recommendations

5.22 **We recommend to European Commission (EC) and national policy makers that any mandatory national biofuels targets required by the Renewable Energy Directive should be set in such a way as to avoid incentivising human rights abuses. Where monitoring through biannual reports detects such effects, sanctions need to be enacted effectively and swiftly. We recommend that the EC develops and implements effective structures of oversight to this effect.**

5.23 **We recommend making certification based on comprehensive standards related to human rights mandatory for all biofuels developed in the EU or imported into the EU, for example as part of a certification scheme such as the one developed by the Roundtable on Sustainable Biofuels. This should be included in the Renewable Energy Directive and national policy instruments such as the UK Renewable Transport Fuel Obligation Order.**

[437] Royal Society (2009) *Reaping the benefits: science and the sustainable intensification of global agriculture*, available at: http://royalsociety.org/WorkArea/DownloadAsset.aspx?id=4294967942.

Principle 2: Environmental sustainability

Biofuels should be environmentally sustainable[438]

> **"[It is necessary to] establish an international certification system that verifies the sustainability of any given biofuel based on a range of factors like environmental, climate, and social."**[439]
>
> **"If regulation or certification of biofuels prove successful, it could become a showcase for sustainable agriculture…"**[440]
>
> **"…the genetic modification of feedstock plants to increase biofuel processing efficiency is an issue of greater public concern, as it represents a wider environmental release."**[441]
>
> **"New genetic engineering strategies, for example, in developing drought-resistant crops have distinct advantages for water savings."**[442]

5.24 Similar issues to those described in the previous section underlie some of the current environmental problems of biofuels production. Biofuels targets such as those included in the RED could, through their magnitude, lead to violations of our Ethical Principle 2, because they encourage – necessitate – a rapid expansion of current biofuels production and use. Such rapid expansion is unlikely to be environmentally sustainable because of direct and indirect land use change, the relatively poor environmental performance of some current biofuels feedstocks, and the import of biofuels, sometimes from countries with less stringent sustainability regulations. As we noted above, initiatives such as that of the RSB cover environmental sustainability in addition to protection of basic human rights. In this section we focus on the environmental implications of current biofuel-specific policies.

Biofuel-specific policies

5.25 In the UK, to fulfil the targets set out in the RTFO, most of the biofuels are currently imported. Ninety-three per cent of the fuel from UK feedstocks met environmental sustainability standards during 2009–2010, but overall only 31 per cent of biofuels used in the UK met an environmental standard (compared with a target of 50 per cent).[443]

5.26 The RED includes standards on the protection of areas of high biodiversity and that are high in sequestered carbon which are applicable to all biofuels developed from food crops. The standards apply to biofuels that are used towards the EU renewable energy target regardless of where the feedstock was produced. The RED also reports to the European Parliament whether biofuels source countries have ratified and implemented some general policies, including the Cartagena Protocol on Biosafety[444] and the Convention on International Trade in Endangered Species of Wild Flora and Fauna.[445] An important feature of sustainability criteria as envisaged by the RED is that biofuels should not be sourced from primary forests, or from certain temperate and tropical grasslands.[446] EU standards relating to other environmental concerns

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[438] We are aware of the fact that that there is not an accepted definition of 'sustainability' and that, currently, many different things are discussed under this heading. Often, sustainability is taken to include both social as well as environmental aspects of sustainable development, production and use of a given technology, and there are many interpretations as to what each of these elements means. Therefore, and to avoid confusion, we do not use the term sustainability in this report except when it denotes what has often been understood as its core meaning. i.e. the protection of the environment.

[439] Anonymous respondent, responding to the Working Party's consultation.

[440] Anonymous respondent, responding to the Working Party's consultation.

[441] NNFCC, responding to the Working Party's consultation.

[442] Society for General Microbiology, responding to the Working Party's consultation.

[443] Renewable Fuels Agency (2010) *Year two of the RTFO*, available at: http://www.renewablefuelsagency.gov.uk/sites/rfa/files/Year_Two_RTFO_v2.pdf, p16.

[444] Cartagena Protocol on Biosafety to the Convention on Biological Diversity of 2000.

[445] Convention on International Trade in Endangered Species of Wild Flora and Fauna of 1973.

[446] Such as, for example, highly biodiverse savannahs, steppes, scrublands and prairies.

such as soil and water conservation apply only to feedstocks grown in the EU and draw on the standards set in place under the provisions referred to under the Common Agricultural Policy.[447]

5.27 However, the situation is different *outside* the EU. In the RED, approaches to cover the key environmental considerations of biofuels systems outside the EU are expected to be implemented through multilateral and bilateral agreements, and voluntary international or national schemes. If these fail to materialise, producers and suppliers of biofuels will be required to report on key environmental considerations to Member States. Such provisions carry the same difficulties in implementation and enforcement that were mentioned with regard to human rights protection above – they might lack sufficient 'bite'. For example, a substantial portion of the biodiesel counted towards the UK's RTFO in 2009–2010 was made from palm oil from Malaysia (73 million litres).[448] Only approximately one-quarter of that met a qualifying environmental standard.[449] Some of the dangers to the environment which have been linked to the expansion of palm oil production in Malaysia, such as the destruction of rainforest and loss of biodiversity, have been outlined in Chapter 2. In order to avoid such impacts, international agreements need to have sufficient force behind them.

5.28 The UK has to adhere to the EU standards but the UK RFA also issues certificates based on the RTFO-Meta standard which, alongside the social criteria mentioned in the previous section, includes criteria for environmental sustainability, covering protection of biodiversity. In the US, the Renewable Fuel Standard (RFS) programme mandates biofuels targets but only addresses one aspect of environmental sustainability related to GHG reduction. There are, therefore, differences between countries and regions in how and whether environmental sustainability of biofuels systems is addressed in specific biofuels policies.

5.29 Concerns over the environmental sustainability of biofuels have led a number of governments, and intergovernmental and international organisations, non-governmental organisations (NGOs) and the private sector to develop sustainability standards for biofuels that are, or could be, used to support environmental policies, as described under our Principle 2. Elements or criteria relating to environmental sustainability, such as biodiversity protection, soil and water quality, protection of carbon-rich lands, and GHG emissions, are also developed in these standards. Some of these are more stringent than the regulatory standards included in the RTFO, the RFS and the RED. They cover a greater range of environmental issues, such as soil and water conservation, and could be used by governments or the private sector; the RSB (see Box 5.3 above) is one such standard. Standards are also being created for specific crops by producer groups, such as the Roundtable on Sustainable Palm Oil[450] and the Better Sugarcane Initiative.[451] In addition, some organisations and groups of stakeholders are providing guidance to national authorities on biofuels production within their territories, such as the Global Bioenergy Partnership,[452] with the aim of making biofuels production more sustainable.

Challenges for the future: sustainability standards and certification

5.30 Overall, existing policies, standards and targets to ensure sustainability, good stewardship of biofuels production and thus adherence with Principle 2 are weak. Either they include no environmental standards or they do not cover all biofuels. For instance, EU sustainability standards do not cover all new approaches to biofuels development. Neither do they cover all biofuels currently used within the EU, but only those used to comply with the RED, renewable

[447] Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16, art 17.
[448] Renewable Fuels Agency (2010) *Year two of the RTFO*, available at: http://www.renewablefuelsagency.gov.uk/sites/rfa/files/Year_Two_RTFO_v2.pdf, p50.
[449] The Renewable Fuels Agency gives the percentage of palm oil diesel (most of which originates in Malaysia) certified by the standard of the Roundtable on Sustainable Palm Oil, see: Renewable Fuels Agency (2010) *Year two of the RTFO*, available at: http://www.renewablefuelsagency.gov.uk/sites/rfa/files/Year_Two_RTFO_v2.pdf, p36.
[450] Roundtable on Sustainable Palm Oil (2011) *Who is RSPO?,* available at: http://www.rspo.org/.
[451] Bonsucro (2011) *Better Sugar Cane Initiative*, available at: http://www.bettersugarcane.org/.
[452] Global Bioenergy Partnership (2011) *About GBEP*, available at: http://www.globalbioenergy.org/.

energy obligations or subsidies. The voluntary sustainability standards for biofuels and related policies are works in progress, and they include a number of unresolved issues and imperfectly defined concepts which if not resolved will limit their effectiveness.

5.31 Moreover, environmental sustainability of biofuels systems is a global problem owing to indirect land use change, GHG emissions and international trade in feedstocks. Current policies are disparate across countries and could benefit from harmonisation, and the large number of stakeholders currently developing standards and certification systems is likely to cause confusion among end users. A multitude of competing schemes will limit their credibility, create market-access difficulties and limit their effectiveness, especially if slightly different schemes are adopted by countries following the RED's recent suggestion.[453] Some organisations, including industry stakeholders, are therefore calling for one meta-standard that will be applicable on an international scale but getting agreement on such a standard is likely to be challenging.

Technology-support policies

5.32 Technological advances have a substantial role to play in reducing the environmental impacts of biofuels by increasing the efficiency of biofuels production at all points in the supply chain. As described in Chapter 3, there is considerable scope to achieve this through a wide range of technological advances ranging from improved water and fertiliser-use efficiency and pest resistance in biomass crop production, to enzymes modified using biotechnology to digest lignocellulose more efficiently. Biotechnologies for genetic improvement, including advanced plant breeding strategies and genetic modification, provide a whole repertoire of helpful tools to enhance environmental performance (see Box 5.5).

Box 5.5: Biotechnologies for genetic improvement of biofuels: examples

Advanced plant breeding strategies for biofuels

Advanced plant breeding strategies can be used to test plant hybrids and to select the variety with a desired trait. For example, Rothamsted Research in collaboration with the University of York is endeavouring to identify markers for the genes in willow that allow it to be grown as short rotation coppice. It is hoped that these markers can then be used to accelerate breeding to develop high biomass yield.[454]

Genetically modified poplar

Feedstocks can be modified to express traits that benefit biofuels production. For example, genetically modified poplar trees are currently under development. Through modified connections within the lignocellulose, the wood provides a more accessible source of cellulose for lignocellulosic bioethanol.[455] The increased accessibility of sugars would have an important positive impact on increasing yields and thus on land use and environmental performance.

Genetically modified enzymes for processing

Novozymes,[456] a company specialising in enzyme production, has used genetic modification to develop a cellulase complex that enables more efficient and cost-effective processing of lignocellulosic ethanol. It can be used with a variety of feedstocks and process technologies, and is claimed to produce significantly higher conversion yields, leading to lower processing costs.[457] More efficient processing of lignocellulose increases the amount of biofuel produced per unit biomass input, thus potentially improving life cycle assessment and the economic performance of biofuels production.

[453] European Commission (2010) *Communication from the Commission on voluntary schemes and default values in the EU biofuels and bioliquids sustainability scheme*, available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2010:160:0001:0007:EN:PDF.

[454] Rothamsted Centre for Bioenergy and Climate Change (2011) *Accelerating breeding for biomass yield in short rotation coppice willow by exploiting knowledge of shoot development in* Arabidopsis, available at: http://www.rothamsted.ac.uk/Research/Centres/ProjectDetails.php?Centre=BCC&ProjectID=4840.

[455] Penn State Live (28 Dec 2008) *Modified plants may yield more biofuel*, available at: http://live.psu.edu/story/36682.

[456] Novozymes (2011) *About us – rethink tomorrow*, available at: http://www.novozymes.com/en/about-us/Pages/default.aspx.

[457] Novozymes (2011) *Novozymes Cellic® CTec2*, available at: http://www.bioenergy.novozymes.com/cellulosic-ethanol/cellic-product-information/.

5.33 In keeping with earlier Nuffield Council reports,[458] we believe that technologies for genetic improvement could be important tools in achieving a sustainable increase in biofuels production without endangering the environment. Regarding genomics- and marker-assisted breeding strategies and in particular genetic modification, we encourage the development of policies to capture the benefits of these technologies in biofuels development, at the same time ensuring that appropriate regulatory systems in place are able to minimise any relevant risks. This applies equally to the introduction of new non-native plants, such as foreign crops, through to the application of nascent technologies such as synthetic biology.[459]

Recommendations

5.34 **We conclude that the best possible standard of environmental sustainability should be developed for biofuels production, for example by an international organisation already working towards such a standard, such as the United Nations Environment Programme. This standard should be implemented as part of a proportionate biofuels certification scheme. This should be achieved in such a way as to prevent displacement and/or the leakage of unsustainable practices into other forms of agriculture.**

5.35 **Policies are needed to investigate the application of biotechnologies for genetic improvement of crops where this has the potential to support the environmental performance of biofuels production, with appropriate regulatory oversight.**

Principle 3: Climate change

Biofuels should contribute to a net reduction of total greenhouse gas emissions and not exacerbate global climate change

> **"In absence of…proper methodologies allowing a full monitoring of national and international iLUC impacts…the application of a default iLUC GHG factor is viable in the short term."**[460]
>
> **"Until better safeguards against iLUC are in place in a country, imports of biofuel feedstocks from that country should be banned."**[461]
>
> **"Land use change is a big [myth] invented by [opponents] to biofuels...It is wrong to concentrate on the few bad exceptions (which of course are not tolerable and have to be avoided)."**[462]
>
> **"There is a danger that the EU (and even more so the UK) pose the iLUC question in such a way that it can never be answered, and succeed only in slowing down the development of a much needed industry [in these countries]."**[463]
>
> **"EuropaBio believes that the best approach to tackle any land use change is through the development of integrated and global measures to address agriculture land use efficiency and emissions."**[464]

5.36 At first sight, Principle 3 seems to be a straightforward requirement that is already embedded in current and emerging policy and regulations on biofuels in the US, the EU and the UK.

[458] Nuffield Council on Bioethics (2004) *The use of genetically modified crops in developing countries: a follow-up Discussion Paper*, available at: http://www.nuffieldbioethics.org/sites/default/files/GMper cent20Cropsper cent20Discussionper cent20Paperper cent202004.pdf; Nuffield Council on Bioethics (1999) *Genetically modified crops: the ethical and social issues*, available at: http://www.nuffieldbioethics.org/sites/default/files/GMper cent20cropsper cent20-per cent20fullper cent20report.pdf.

[459] Synthetic biology is emerging as an important new technique for the development of biofuels. Synthetic biology can be understood as an approach that draws on principles elucidated by biologists, chemists, physicists and engineers deliberately to redesign existing or design and construct novel biological systems and organisms, devices and systems. A range of definitions of synthetic biology have been proposed by a number of scientific and advisory bodies. Our definition here follows the definition in: Royal Society (2008) *Synthetic biology: scientific discussion meeting summary*, available at: http://royalsociety.org/WorkArea/DownloadAsset.aspx?id=5486. In the context of biofuels it can be seen as an extension of genetic modification technology.

[460] International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), responding to the Working Party's consultation.

[461] Professor Keith Smith, responding to the Working Party's consultation.

[462] Anonymous respondent, responding to the Working Party's consultation.

[463] Swan Institute, Newcastle University, responding to the Working Party's consultation.

[464] EuropaBio, responding to the Working Party's consultation.

However, the three drivers of biofuels development outlined in Chapter 1 have different objectives and can conflict with each other. Biofuels policies that are implemented mainly with the aim of improving economic development and/or energy security and therefore encourage industrialised production of large volumes of biofuels can lead to production pathways that do not generate significant GHG emissions savings.

Biofuel-specific policies

5.37 The best-known example of a problematic policy of this nature comes from corn-based ethanol production in the US. While producers of corn ethanol, over a relatively short period of time, succeeded in producing significant quantities of biofuels and generating income, largely from subsidies, the low or allegedly negative GHG emissions savings from corn ethanol have been a matter of much debate (as discussed in Chapter 2).

5.38 Corn-based ethanol production has been supported by several policies (see Chapter 2), and by high oil prices. National policies such as tax breaks and other subsidies for biofuels production, if they are not accompanied by stringent requirements for GHG emissions savings, may lead to a violation of Principle 3. This was recognised in the US where the Energy Independence and Security Act of 2007 required that any biofuels produced after enactment (i.e. those now used to comply with the new Renewable Fuels Standard) generate at least 20 per cent GHG emissions savings.[465]

5.39 International mandates and targets may incentivise scaling up of biofuels production in countries that do not have climate change mitigation policies, and this may lead to production of biofuels with low GHG emissions savings (unless sustainability safeguards are applied to the trade in biofuels). Environmental protection and climate change mitigation are intertwined – protecting carbon sinks[466] and biodiverse land amounts to, among other results, avoiding GHG emissions and both are currently negatively affected by existing policies enabling rapid biofuels development.

5.40 The situation in Europe is different. Both climate change mitigation and the transition towards a low carbon economy with reduced GHG emissions has become a primary driver for biofuels developments. The RED specifies requirements for net GHG emissions savings from biofuels supplied in the EU: the current target of at least 35 per cent of emissions saved, rising to 50 per cent from 1 January 2017; and at least 60 per cent savings from 1 January 2018 for biofuels installations starting on or after 1 January 2017.[467]

5.41 The RED can, however, be criticised as an instrument enabling Europe to achieve its climate change goals, through incentivising the rest of the world to help fulfil these goals, to the detriment of their own interests or global emission targets. Without a policy instrument such as a certification scheme that ensures that all biofuels imported into Europe and counted towards the European target deliver GHG emissions savings throughout their whole production process ("from field to tank"), the RED could be seen to be 'outsourcing' the pressing problem of climate change mitigation. There are provisions for this within the RED although their effectiveness needs to be tested through actual implementation.

Challenges for the future: measuring GHG emissions

5.42 The recommendation that GHG emissions be measured in full life cycle assessments (LCAs) raises manifold difficulties itself. A number of these are fundamentally methodological and are

465 s202 Energy Independence and Security Act of 2007.
466 A carbon sink is anything that absorbs more carbon that it releases, for example forests.
467 Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16, art 17.2

related to the purposes of LCA and the questions which it aims to answer. In the context of biofuels *regulation*, it is necessary to answer the question: "Who is responsible for any given net change in total GHG emissions due to biofuels production?" In contrast, for biofuels *policy analysis*, the relevant question is: "What is the overall effect on GHG emissions of a policy which promotes production of a biofuel?" In the parlance of the field, the biofuels regulation methodology is equivalent to *attributional* LCA and the biofuels policy analysis methodology is equivalent to *consequential* LCA.[468]

5.43 The choice of methodology determines what is included and how, and this in turn affects the resulting estimates of net GHG emissions savings. Contentious areas of inclusion are the key elements: co-product allocation; treatment of wastes and residues as biomass feedstocks for biofuels production; and direct land use change (dLUC) and indirect land use change (iLUC) (see also Box 2.8 in Chapter 2).

5.44 Each methodology brings different challenges. In attributional LCA, the challenge is the allocation of responsibility for GHG emissions: producers have immediate influence over their so-called 'direct' GHG emissions, which arise from activities such as their combustion of fossil fuels during processing. However, 'indirect' GHG emissions also arise, and these can be significant and sometimes greater than direct GHG emissions. For example, a biofuels producer may purchase chemicals for use in processing. There will be GHG emissions associated with the original production of these chemicals. Such indirect GHG emissions are normally attributed to the biofuels producer. In terms of LCA, this approach for incorporating GHG emissions that occur further from the immediate production process is referred to as "expanding the system boundary". However, the act of expanding system boundaries dilutes a producer's control and influence over emissions produced and thus their responsibility for the emissions associated with the biofuels delivered. Attributing responsibility for increasingly remote emissions can thus become increasingly arbitrary.

5.45 In consequential LCA, it is necessary to expand the system boundary to its full extent so that the global consequences are incorporated into the GHG emissions calculations. It does not attempt to attribute all these consequences to a given producer. Instead, its purpose is to link initial cause to ultimate effect. However, this implies global modelling with a vast scope that is capable of tracing all connections and evaluating them in terms of resulting GHG emissions. The data requirements of such modelling are extremely difficult. For example, the consequences for GHG emissions of purchasing a given chemical might be easy to calculate on a small scale but, if the policy is globally significant, this could encourage major increases in production of that chemical, requiring new manufacturing facilities to be constructed. These facilities may incorporate new technologies so that GHG emissions might be very different, positively or negatively depending on the technology adopted, from those associated with existing facilities. Hence, consequential LCA has to take global dynamics and scale into account in assessing likely connections and consequences, and evaluating GHG emissions is an extremely challenging *ex ante* activity involving future considerations, whereas in attributional LCA evaluation is an *ex post* activity that is only concerned with the present or the recent past.

5.46 It follows that the determination of iLUC, co-product allocation and the treatment of residues and wastes are all important challenges for GHG emissions calculations. They are addressed in the RED but they are also the subject of controversial debates, and much uncertainty surrounds the question of how to determine them in the best way (see Box 5.6). However, considerable controversy can be removed by appreciating the distinction between attributional LCA (for biofuels regulation) and consequential LCA (for biofuels policy analysis) and, thereby, understanding and accepting that different approaches legitimately answer different questions. Furthermore, by adopting the correct form of LCA in the relevant circumstances, a logically

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[468] Brander M, Tipper R, Hutchinson C and Davis G (2009) *Consequential and attributional approaches to LCA: a guide to policy makers with specific reference to greenhouse gas LCA of biofuels*, available at: http://d3u3pjcknor73l.cloudfront.net/assets/media/pdf/approachesto_LCA3_technical.pdf.

coherent and consistent basis for GHG emissions calculations can be devised, justified and applied rigorously in practice.

Box 5.6: Challenges in measuring GHG emissions

The net GHG emissions savings of a biofuel are defined as the percentage difference in total GHG emissions of a biofuel relative to those of a conventional fuel that is displaced.[469] Net reductions in total GHG emissions arise when net savings exceed zero per cent and are, therefore, positive. Conversely, where net savings are equal to or less than zero per cent, the biofuel generates the same or more GHG emissions than the conventional fuel that it is intended to replace.

In general, the methodology for calculating GHG emissions is based on basic LCA principles (see Box 2.8 in Chapter 2) and the choice of methodology depends on the question being addressed.

Land use change

For dLUC, the EC has determined that the most effective approach is to ensure that no land with high carbon stocks is used for the cultivation of biofuels feedstocks.[470] However, how such land is defined is still unclear and this is one of the difficulties in formulating environmental sustainability standards.

To address iLUC, the RED proposes that the EC should develop a methodology to minimise GHG emissions associated with iLUC, possibly by means of a factor to be applied to relevant biofuels.[471] A final decision has not been made on which methodology to use[472] but, in any case, changes will not apply until 31 December 2017 to any biofuels installation that is in production before the end of 2013, provided that it currently achieves at least 45 per cent net GHG emissions savings (this is frequently referred to as 'grandfathering').

The difficulty in incorporating iLUC into standards is where to set the boundaries and how to gauge whether iLUC has occurred.

Residues and wastes

The RED also specifies[473] that all associated GHG emissions prior to the collection of "residues and waste products"[474] – which are to be used as biofuels feedstocks – should be excluded from calculations. In practice, most of these residues and wastes are co-products of other processes. Hence, for consistency, so-called 'upstream' GHG emissions associated with their production should be subject to the specified co-product allocation procedure. In the case of the RED, this co-product allocation is based on the energy content of the co-products and involves estimating and comparing "energy flows" associated with each co-product on the basis of its energy content multiplied by its quantity.

5.47 Of all the issues concerning the evaluation of GHG emissions for biofuels, the debate over iLUC has been the most contentious. In the absence of effective global action, the potential impact of biofuels via iLUC has been something of a 'lightning rod' for concerns over destruction of important carbon stocks, such as rainforests and peatland. It is now generally appreciated that biofuels production is one of many developments that can generate direct and indirect pressure on LUC and lead to the destruction of important carbon stocks. It is recognised that dLUC for biofuels production should be avoided and biofuels regulations can require this. However, such regulations, which only apply to one form of land use, are a very ineffective way of dealing with the destruction of carbon stocks. Instead, a much better approach is for internationally agreed

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[469] Mathematically: $S = [(G_a - G_b)/G_b] \times 100$ per cent
where S = net GHG emissions savings of a biofuel (per cent)
G_a = total GHG emissions of a conventional fuel (kg eq. CO_2/MJ)
G_b = total GHG emissions of a biofuel (kg eq. CO_2/MJ)

[470] Commission Decision of 10 June 2010 on guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC (2010/335/EU) [2010] OJ L151/19; Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16, art 17.3–17.6.

[471] Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16, recital 85. It is implied that this factor might apply to biofuels derived from non-food cellulosic and lignocellulosic biomass feedstocks as well as biofuels produced from food crops.

[472] A report discussing some future policy options has recently been published; see: European Commission (2010) *Report from the Commission on indirect land-use change related to biofuels and bioliquids*, available at: http://ec.europa.eu/energy/renewables/biofuels/doc/land-use-change/com_2010_811_report_en.pdf. The final impact assessment together with a legislative proposal is expected to be published in July 2011.

[473] Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [2009] OJ L140/16, art 19.3.

[474] These are specified as various forms of agricultural crop residues and residues from processing chains (other than biofuels processing chains) with no potential for food or feed use.

policies, with strong monitoring and policing measures, to prevent the loss of major carbon stocks. This would address LUC directly at the point where it takes place and by those who are immediately responsible. If such a more targeted approach to LUC were successful, and as it will have to be as part of a serious international response to global climate change, the need to consider iLUC would become irrelevant for biofuels or any other activity that involves significant land use. In our subsequent recommendation, we therefore suggest more holistic changes to policy than have recently been put forward, for example by the EC.[475] The issue that would then remain would be whether sufficient land is available for all future land uses including the cultivation of crops for biofuels. This requires substantial information, which currently does not exist, on global land use to consider the potentially constrained supply against diverse and competing demand. The resolution is a matter for international policy that also recognises the need to choose between competing options (see Chapter 6).

Technology-support policies

5.48 Some new approaches to biofuels development are likely to fare well in terms of their GHG emissions savings. One technological breakthrough that could enable the scaling up of production and significant GHG emissions savings is the use of algal biofuels produced using nutrient-rich wastewater and carbon dioxide-rich flue gas from power stations. Indeed, some biofuels may be able to avoid any significant land use change. Implementation of the RED at individual EU Member State level will help to determine whether there is support for such new biofuels technologies.

5.49 In the UK, it is likely that, unless support for specific new technologies is made explicit, such support can only function indirectly. For example, under the RTFO,[476] suppliers are obliged to reach target contributions and target savings and they are penalised financially if they do not. There is thus pressure to adopt the technologies that enable developers to avoid penalties, and this may lead them to choose technologies that are already established over those which need further development and investment. Targets are rather blunt instruments to promote new technologies. We therefore conclude that specific biofuels policy should include instruments to stimulate the development of biofuels that will need little land and few other resources, and that produce significant GHG emissions savings (with some safeguards around fair cost–benefit sharing, as set out below).

Recommendations

5.50 **We recommend to the European Commission (EC) Directorate-General for Energy and Transport and the UK Department for Transport, Department of Energy and Climate Change, Department for Environment, Food and Rural Affairs and Department for International Development that different biofuel types be certified on the basis of their life cycle greenhouse gas emissions according to attributional life cycle assessment (LCA), and based on a single international standard. This requires elucidation of the important distinction between attributional and consequential LCA. Such certification should be complemented by a robust regulatory mechanism to ensure compliance. The standard should be drawn up by the original authors of the Renewable Energy Directive, including the Joint Research Centre and the subsequent regulators who must translate EC policy into individual Member State practice. The standard should be extended globally, for example in cooperation with the United Nations Framework Convention on Climate Change.**

5.51 **We recommend to the European Commission Directorate-General for Energy and Transport and the UK Department of Energy and Climate Change, as well as to the United**

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[475] European Commission (2010): *Report from the Commission on indirect land-use change related to biofuels and bioliquids*, available at: http://ec.europa.eu/energy/renewables/biofuels/doc/land-use-change/com_2010_811_report_en.pdf.
[476] The Renewable Transport Fuel Obligations Order 2007 amended by The Renewable Transport Fuel Obligations (Amendment) Order 2009, art 21.

Nations Framework Convention on Climate Change Secretariat, that policies on land use change should be set within a wider framework of global agreement on a coordinated response to climate change, which directly tackles land use change, with strong international and local measures to prevent destruction of high carbon stocks, thereby eliminating or minimising harmful direct or indirect land use change.

5.52 In order to support such initiatives and in compliance with attributional LCA, greenhouse gas (GHG) emissions calculations for *regulatory* purposes should be based on the concept of economic responsibility of relevant operators, which means that the use of residues and wastes as biomass feedstocks, and allocation between co-products, should be based on price, and that GHG emissions from iLUC should be excluded from calculations. GHG emissions calculated for *policy* purposes and related to the issue of iLUC for biofuels and all other agricultural activities should be addressed by consequential LCA with due regard given to the difficulties and uncertainties associated with modelling global iLUC.

5.53 **Specific biofuels policies should include technology-relevant instruments to stimulate the development of those biofuels and biofuels crops that can be demonstrated to produce significant net greenhouse gas emissions savings, for example through high biomass yield with minimal inputs and land use. Such instruments could, for example, be developed by national research councils.**

Principle 4: Just reward

Biofuels should develop in accordance with trade principles that are fair and recognise the rights of people to just reward (including labour rights and intellectual property rights)

> **"New mass products always impact on the small scale farmer and worker negatively unless they are protected in participatory schemes (shares, minimum prices regulations, etc.)"**[477]
>
> **"Biofuel distilleries generally must be large to be economically efficient which leads to concentration of profits in the hands of a few; however farmer alliances and multiple-option crops can significantly empower farmers in their relationships with distillers."**[478]

5.54 As has been mentioned, one of the facets of biofuels is the complexity and geographic scope of the value chains through which they are produced, processed and distributed. In many respects, these value chains mirror the existing inequalities that characterise agricultural production and they may exacerbate them. These need to be considered from the perspective of fair trade in order to comply with just reward. Another important aspect of just reward is how IP is approached, and we turn to this in the second half of this chapter.

Biofuel-specific policies

5.55 Biofuels blending targets are a policy that has the potential to threaten the basis of fair trade in biofuels. Such targets promote investment in developing country biofuels feedstock production as the EU cannot meet them through its own feedstock production. This increase in new forms of export agriculture has multidimensional implications for fair trade, of which there are environmental and human rights dimensions such as effects on food security. Such examples have already been mentioned.

5.56 Much investment in biofuels feedstock production in developing countries has been accused of not benefiting either smallholders or farm labourers. Experience in Brazil, for example, has shown that workers producing sugar for bioethanol production can suffer low wages, job

[477] Individual at Rothamsted Research, in the institute's response to the Working Party's consultation.
[478] International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), responding to the Working Party's consultation.

insecurity and often dangerous working conditions (see Chapter 2). An Oxfam report[479] from 2008 suggests that, as Brazil's sugar cane feedstock production matures and mechanises, job opportunities shrink and farm labour is dramatically cut. On the other hand, the potentially very large expansion of the industry might provide a significant number of new, often better jobs (running the machines) to the displaced workers. Brazil is an interesting example in this respect. One of the major reasons for the improved economy in Brazil is the dramatic growth in commodity-based exports, and sugar cane and ethanol are among these commodities. This kind of economic growth (along with some social programmes, for example funded by the World Bank) has had a large impact in reducing poverty: poverty reduced dramatically in Brazil from 20 per cent of the population in 2004 to 7 per cent of the population in 2009.[480] This could be seen as a successful example of 'trickle-down economics', where an economic boom alleviates some of the poverty in a population, and, in Brazil, biofuels probably played some part in this.

5.57 However, the EU's biofuels targets have acted as a stimulus to oil palm production in countries such as Indonesia and Malaysia (see Chapter 2), resulting in the consolidation of oil palm production into large-scale plantations, and this has been accused of squeezing out smallholders who are unable to compete. Likewise, investment in jatropha (see Chapter 3) as a source of oil for biodiesel production in Africa could raise some difficult issues. Countries such as Ethiopia are investing in large-scale jatropha plantations on the basis of targets. Such countries might become vulnerable to changing demand, for example following EU policy changes.

5.58 The protection of labour rights to ensure adequate payment to labourers in all countries producing biomass feedstocks for EU biofuels supplies is addressed in the RED under sustainability criteria with requirements for ratification and implementation of relevant Conventions of the International Labour Organization,[481] with reports on this every two years. Again, a key issue is whether countries outside the EU adhere to these protective policies when faced with strong incentives for scaling up their biofuels production (i.e. biofuels targets). Concerns noted above regarding the favoured acquisition of land in countries with lax standards are also relevant to fair trade and fair rewards.

Challenges for the future: Fairtrade schemes

5.59 Ensuring fair reward in global patterns of agriculture is very difficult. This is due to entrenched global inequalities and the difficulties of governing complex value chains that cross international boundaries and intersect with many different sets of interests. One of the approaches that have achieved a measure of success in generating fair wages and fairer trade relationships has been the introduction of Fairtrade[482] schemes, which recognise the rights of people to just reward and thus conform to the ethical value of solidarity (see Box 5.7).

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479 Oxfam International (2008) *Another inconvenient truth: how biofuels policies are deepening poverty and accelerating climate change*, available at: http://www.oxfam.org/sites/www.oxfam.org/files/bp114-inconvenient-truth-biofuels-0806.pdf, p27.

480 World Bank (2010) *Brazil country brief*, available at: http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/LACEXT/BRAZILEXTN/0,,menuPK:322351~pagePK:141132~piPK:141107~theSitePK:322341,00.html#economy.

481 Convention concerning Forced or Compulsory Labour; Convention concerning Freedom of Association and Protection of the Right to Organise; Convention concerning the Application of the Principles of the Right to Organise and to Bargain Collectively; Convention concerning Equal Remuneration of Men and Women Workers for Work of Equal Value; Convention concerning the Abolition of Forced Labour; Convention concerning Discrimination in Respect of Employment and Occupation; Convention concerning Minimum Age of Admission to Employment; and Convention concerning the Prohibition and Immediate Action for the Elimination of the Worst Forms of Child Labour.

482 In this report, 'fair trade' is used as a generic term, while 'Fairtrade' relates to the Fairtrade brand and movement.

Box 5.7: Fairtrade schemes

There is no universally agreed definition of fair trade but the Fairtrade Labelling Organizations (FLO) International uses the following broad definition: "Fairtrade is an alternative approach to conventional trade and is based on a partnership between producers and consumers. Fairtrade offers producers a better deal and improved terms of trade."[483] Our Principle of just reward, including fair trade, relates to the creation of greater solidarity between consumers and producers and is embodied in this definition, but the 'Fairtrade' movement has also made a significant effort to incorporate this Principle into certification schemes.

Since the 1980s there has been a rapid growth in certification schemes run by not-for-profit Fairtrade labelling organisations. In 1997, a process of convergence among labelling organisations led to creation of FLO International, an umbrella organisation whose mission is to set the Fairtrade standards, to support, inspect and certify disadvantaged producers, and to bring clarity to the Fairtrade message globally.

In 2002, FLO launched for the first time an International Fairtrade Certification Mark. The goals of the launch were to improve the visibility of the Mark in supermarket shelves and facilitate trade for Fairtrade products. Fairtrade certification schemes are now used for dozens of products, including coffee, tea, rice, bananas, cotton, sugar, honey, quinoa and nuts.

Yet, Fairtrade certification schemes have been criticised by a variety of researchers and commentators for a number of reasons. The *Financial Times* found that the certification was often being used by non-certified producers[484] and that some wage workers were hired by Fairtrade producers who were in violation of the minimum wage and Fairtrade standards.

The Adam Smith Institute claimed in 2008 that Fairtrade has had little impact on the percentage of final sale value ending up with producers, as only 10 per cent of the Fairtrade premium for a cup of coffee at a popular coffee chain goes to purchase Fairtrade coffee beans instead of standard beans.[485]

Some Fairtrade supporters[486] have noted that large certification schemes tend to favour larger producers. The Fairtrade brand can in some circumstances undermine essential broader principles such as the building of solidarity between consumers and producers and shortening supply chains between them. Thus, while trade principles that are fair should apply to procurement of feedstocks for biofuels, care should be taken before endorsing particular certification schemes.

5.60 Given the limitations of current Fairtrade schemes, it is not clear that their simple application is useful and sufficient. Instead, trade principles that are fair should be incorporated into the efforts described under the other Principles above to establish sustainable biofuels production, for example as part of certification. These principles should respond to the particularities of biofuels value chains and also correspond with some of the complexities of competing and often contradictory goals and systems of governance that currently drive investment in biofuels.

5.61 Generating multidimensional certification for the fair trade of biofuels represents an important step towards ensuring the environmental, economic and developmental sustainability of global trade in biofuels.[487] As yet, no internationally agreed biofuels fair trade principles exist. There are examples of nationally agreed principles, notably in Brazil with its 'Social Fuel Seal' for biodiesel,[488] and there may be lessons to be learnt from this case. Lessons may also be drawn from fair trade principles in other contexts, but in many ways biofuels will be more difficult to certify as 'fair trade' given the range of impacts and implications involved. Impacts are often subjective, little understood and difficult to assess and we need to understand the complexities

483 Fairtrade International (2011) *What is Fairtrade?*, available at: http://www.fairtrade.net/what_is_fairtrade.0.html.
484 The Financial Times (8 Sep 2006) *The bitter cost of 'fair trade' coffee*, available at: http://www.ft.com/cms/s/2/d191adbc-3f4d-11db-a37c-0000779e2340.html.
485 Sidwell M (2008) *Unfair trade*, available at: http://adamsmith.org/images/pdf/unfair_trade.pdf, p11.
486 Such as The Lorna Young Foundation and Fairtrade entrepreneurs Jurang.
487 Woods J and Diaz-Chavez R (2007) *The environmental certification of biofuels: discussion paper no. 2007-6*, available at: http://www.fao.org/uploads/media/0712_Joint_transport_research_centre_-_The_environmental_certification_of_biofuels_-_DiscussionPaper.pdf.
488 The Brazilian Ministry of Agrarian Development issues the 'Social Fuel Seal' to biodiesel producers who promote social inclusion and regional development by generating jobs and income for family farmers who are part of the Brazilian National Program to strengthen family agriculture; for more details see: Ministério do Desenvolvimento Agrario, Secretaria da Agricultura Familiar (2010) *Biodiesel – o selo combastível social*, available at: http://portal.mda.gov.br/portal/saf/programas/biodiesel/2286313 *[in Portuguese]*.

of developing a system of certifying biofuels as fairly traded and not to rush into making mistakes or mis-calibrations.

5.62 Relevant uncertainties result from the complexity of biofuels supply chains, from methodological and scientific issues, and from differing dynamic societal and environmental interactions. Assessing the net impacts of biofuels production and use on fair trade is thus fraught with difficulty.[489] For example, strict guidelines in Indonesia regarding the use of environmental impact assessments and government regulation of new plantations via licensing and certification are claimed to have had little impact on managing plantation development. A Friends of the Earth report in 2009 points to the existence of 'fast track' licensing, with *de facto* waiving of legal requirements designed to protect the environment and local communities, in favour of securing state income. The report indicates that many companies, including subsidiaries of multinational agribusinesses, have commenced plantations without having secured the necessary approvals.[490]

5.63 Development of global certification of fair trade biofuels needs to take account of the relative capacities of countries to enforce the principles on which fair trade is built. Thinking holistically about the global governance of biofuels in terms of the common good is therefore important and the lack of capacity, blind spots and lack of political will which may hinder the development of fair trade in biofuels will lead to demands for more research, analysis and resources. This issue is not specific to biofuels, and we will come back to it in Chapter 6.

5.64 However, the act of attempting to develop trade principles that are fair will draw attention to crucial issues and it is hoped that it will stimulate new forms of analysis that will be able to inform the development of appropriate certification, regulatory and governance schemes, avoiding some of the existing problems.

Recommendations

5.65 **Current and future biofuels blending targets for the EU and UK need to take a long-term view and promote trade principles that are fair. The effects on developing countries of future changes in targets need to be monitored carefully.**

5.66 **Given the limitations of current Fairtrade schemes, we propose that trade principles that are fair be developed as part of sustainable biofuels certification requirements by EU and national stakeholders, such as the authors of the Renewable Energy Directive and the UK Department for International Development. This needs to happen in a proportionate and flexible way to acknowledge the differences between countries and production systems, while at the same time strictly maintaining the protection of vulnerable populations.**

Intellectual property

5.67 There are many justifications for IP, including natural and human rights, incentive theory and reward theory.[491] Intellectual property regimes operate through a paradox: the public benefit of encouraging new innovations is incentivised by the prospect of private property rights over the self-same innovations. The public interest can therefore be jeopardised if the private rights are exercised in ways that prevent or restrict public access to new goods. Principle 4 seeks to find a

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489 Woods J and Diaz-Chavez R (2007) *The environmental certification of biofuels: discussion paper no. 2007-6*, available at: http://www.fao.org/uploads/media/0712_Joint_transport_research_centre_-_The_environmental_certification_of_biofuels_-_DiscussionPaper.pdf.

490 Friends of the Earth (2009) *Failing governance – avoiding responsibilities: European biofuel policies and oil palm plantation expansion in Ketapang District, West Kalimatan, Indonesia*, available at: http://www.foei.org/en/resources/publications/pdfs/2009/european-biofuel-policies-failing-governance-avoiding-responsibilities/view, pp13ff.

491 Hettinger EC (1989) Justifying intellectual property *Philosophy and Public Affairs* **19**: 31–52. See also: MacQueen H, Waelde C, Laurie G and Brown A (2010) *Contemporary intellectual property: law and policy*, 2nd Edition (Oxford: Oxford University Press), chapter 1.

balance between rewarding parties for their innovation and investment while trying to encourage access to knowledge and materials. For example, while human rights support the granting and protection of IP, this cannot come at the cost of other fundamental rights. Moreover, although solidarity demands that knowledge be shared, a way must also be found to support the holders or generators of this knowledge.

5.68 For biofuels in many cases, financial return will only be possible after the investment of very large sums of money in the development of biofuels products, infrastructure and facilities. Intellectual property will undoubtedly play a key role in attempts to secure such a return. The two most relevant intellectual property rights (IPRs) are likely to be: patents over novel inventions that make technical or industrial contributions to human knowledge; and plant variety rights which may be used to protect a new plant variety specifically bred for its use in biofuels production (see Box 5.8).

Box 5.8: Patents and plant variety rights

Patents

Intellectual property offices around the world assess broadly similar criteria to determine whether a new invention is worthy of patent protection.[492] The Patents Act 1977 was enacted to bring the UK in line with the European Patent Convention and these instruments in turn reflect the obligations under the World Trade Organization's (WTO) Agreement on Trade Related Aspects of Intellectual Property Rights[493] (TRIPs). This sets criteria and minimum standards for IP protection to be adopted by WTO members through national legislation. The objective of the TRIPs Agreement is to strengthen and harmonise intellectual property rights around the world. In particular, article 27 requires that patents shall be available for any inventions in all fields of technology.[494]

The areas of biofuels development most likely to attract patents are lignocellulosic or algal developments, or new process technologies for the more efficient development of biofuels from currently used sources. In 1998, the European Parliament passed the Directive on the legal protection of biotechnological inventions, commonly known as the Biotechnology Directive.[495] This Directive sought to clarify the patentability of inventions in the field of biotechnology, including inventions involving plants, by providing clear and effective legal protection.[496] The problem had been that patent law specifically excludes protection for "plant…varieties or essentially biological processes for the production of plants".[497] The Directive and related case law now make it clear that patentability is only excluded with respect to plant varieties as such or to processes for their production consisting entirely of natural phenomena.[498]

The TRIPs Agreement reflects this exclusion in that plants may be excluded from patent protection. However, it goes on to require that, in such circumstances, plant variety protection must be offered by means of a *sui generis* (bespoke) system.[499] Moreover, TRIPs allows for patents and plant variety rights to coexist in countries that so wish. Thus, in another paradox, from a potential exclusion is born the possibility of cumulative protection.[500]

Plant variety rights

Advanced plant breeding strategies as outlined in Chapter 3 could lead to the development of new plant varieties with improved traits suitable in the production of biofuels. These new varieties may be protected under the provisions of the UK Plant Varieties Act 1997.[501] At the EU level, new varieties may be protected under the Community Plant Variety Right

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492 These are that the invention must: i) be novel, in the sense of not having been previously available to the public; ii) demonstrate an inventive step, in the sense that the invention is not obvious to an expert in the field; and iii) demonstrate industrial applicability/utility, in the sense that it can be made or used in a technical field.

493 Agreement of Trade Related Aspects of Intellectual Property Rights of 1994.

494 Ibid, art 27.

495 Directive 98/44/EC of the European Parliament and of the Council of 6 July 1998 on the legal protection of biotechnological inventions, [1998] OJ L213/13.

496 The implementation of the Directive has not been without controversy; see for example: Llewelyn M and Adcock M (2006) *European plant intellectual property* (Oxford: Hart Publishing).

497 Directive 98/44/EC of the European Parliament and of the Council of 6 July 1998 on the legal protection of biotechnological inventions, [1998] OJ L213/13, recital 9.

498 Bostyn SJR (2009) How biological is essentially biological? The referrals to the enlarged Board of Appeal G-2/07 and G-1/08 *European Intellectual Property Review* **31**: 549–58. The Enlarged Board of Appeal at the European Patent Office in December 2010 has now provided further clarification on the meaning of "essentially biological processes"; see: European Patent Office (2010) *No European patents for essentially biological breeding processes*, available at: http://www.epo.org/topics/news/2010/20101209a.html.

499 Agreement of Trade Related Aspects of Intellectual Property Rights of 1994, art 27(3).

500 Westkamp G (2003) TRIPS principles, reciprocity and creation of sui generis types of intellectual property rights for new technology *The Journal of World Intellectual Property* **6**: 827–59.

Regulation.[502] This allows plant breeders to apply for a single EU-wide right to protect their varieties and potentially gives considerable control over the entire European market.

In order to meet their international obligations under TRIPs, some countries joined the International Union for the Protection of New Varieties of Plants (UPOV) and implemented either the 1978 or 1991 versions of the Convention.[503] Other countries have implemented their own plant variety right protection legislation. Few African or Asian countries are members of UPOV[504] and have instead implemented their own plant variety right protection legislation.

5.69 Both the plant variety right and patent regimes can provide a reward for innovation which, at least in part, meets the requirements of Principle 4. Additionally, both regimes contain mechanisms that can help towards the sharing of knowledge and balance the various rights and interests in IP to ensure a just reward.

Balancing rights and interests in intellectual property

5.70 Intellectual property regimes are full of tensions and political agendas. As the above discussion demonstrates, there has been a tendency towards more and stronger IPRs over the years. Moreover, there is a need for bilateral free trade agreements (FTAs) to help states compete in the world market. Intellectual property rights are specifically addressed within these agreements. All EU FTAs seek to strengthen IP legislation, especially in areas such as enforcement, beyond that required by the TRIPs Agreement. This is a common negotiating tactic of developed countries when dealing with developing or least developed countries. These so-called TRIPs-Plus provisions may limit further the latitude that developing countries have under the TRIPs Agreement in implementing IP legislation.[505]

5.71 It is unrealistic and probably economically imprudent to suggest that the number or scope of IPRs should be reduced. A better approach is to recognise the distinction between the existence and the exercise of IPRs. Thus, whereas IP might be claimed over plant varieties, it is important to note that certain flexibilities nonetheless arise which limit the ways in which IPRs can be used against third parties. For example, plant breeders' rights are not infringed by acts done with the objective of breeding, discovering or developing new varieties (although it is likely that a patent over the same material would be infringed). Another approach is to influence the way in which IP is exploited – which is done principally through the grant of licences.

Challenges for the future: the sharing of knowledge – licensing

5.72 A balance between the sharing of knowledge and access to information may best be achieved through appropriate control of licensing practices (see Box 5.9).

Box 5.9: Licensing instruments

Compulsory licence
Under the UK Patents Act 1977, a compulsory licence may be granted in certain restricted circumstances where the public interest is being undermined by the patent holder's behaviour, notably the refusal to use or to license an invention. However, the criteria are strict and the overriding concern has been not to fetter the rights of the patent holder. Accordingly, such licences are rarely, if ever, granted.

Under WTO law, article 31 of TRIPs allows member states to grant compulsory licences where it is in the public interest to

[501] Plant Varieties Act 1997. The criteria for granting protection are that the plant variety must be: i) distinctive; ii) uniform; and iii) stable. It must also be new but in ways far less stringent than those tested under patent law, s4(2) Plant Varieties Act 1997.

[502] Council Regulation (EC) No 2100/94 of 27 July 1994 on Community plant variety rights, [1994] OJ L 227/001.

[503] International Union for the Protection of New Varieties of Plants of 1978 and 1991, Conventions available at: http://www.upov.int/en/publications/conventions/index.html. Countries wishing to join to the 1978 Convention had to deposit an instrument of accession before the first anniversary of the entry into force of the 1991 Convention. All countries wishing to become a member of UPOV must now accede to the 1991 Convention.

[504] International Union for the Protection of New Varieties of Plants (2011) *Members of the International Union for the Protection of New Varieties of Plants*, available at: http://www.upov.int/export/sites/upov/en/about/members/pdf/pub423.pdf.

[505] Matthews D (2010) The Lisbon Treaty, trade agreements and the enforcement of intellectual property rights *European Intellectual Property Rights* **32:** 104–12.

do so. The applicant for such a licence has to comply with a number of qualifying criteria before a licence will be granted. Some of these conditions may be waived in the case of a national emergency or other circumstances of extreme urgency. There has been a lot of debate as to what these terms actually mean and when these provisions can be used.

The Doha Declaration[506] helped to clarify what is meant by "a national emergency or other circumstances of extreme urgency".[507] The Declaration means that each member has the freedom to determine what constitutes a national emergency or circumstances of extreme urgency. The Declaration is also important in that it is now recognised that emergency may not be a short-term problem and measures may be adopted and maintained as long as the underlying situation persists. This has important implications for compulsory licensing of climate change technology including biofuels.

Exclusive licence
An exclusive licence typically grants the licensee an exclusive territory or an exclusive set of customers. The effect is to exclude the licensor either from that geographical territory or those customers for however long the licence lasts.

Sole licence
If the licence is a 'sole licence', this means the licensee is the only licensee in that territory or for that group of customers. This is different from an exclusive licence where the licensor themselves will not compete. Sole licences mean that the licensor remains free to compete with the licensee but simply that other licensees will not be granted.

Non-exclusive licence
A non-exclusive licence leaves the licensor free to compete or appoint other licensees in the territory without restriction.

Cross-licence
In the realms where dual protections exist and where it is not possible to proceed with work in one section without fear of violating an IPR in another, the Biotechnology Directive, article 12 provides for the grant of non-exclusive compulsory cross-licences.

5.73 Many consider compulsory licence provisions as a form of safety valve within IP law, simply designed to moderate the excessive demands of licensors. The compulsory license system is too complex and confrontational to be used except in extreme circumstances to gain access to technology. There is little support in practice for such indiscriminate use of compulsory licences, and this is also the view of the Council. However, more imaginative uses of licensing are possible.

5.74 Contrary to much speculation and despite a few high profile cases, there is little strong evidence to suggest that IPRs holders are using their rights aggressively and in ways that are having a chilling effect on the public interest. This is not to suggest that problems do not exist with how IP is exploited, but it does indicate that there is hope for the way forward. For example, the Organisation for Economic Co-operation and Development (OECD) has produced a set of guidelines which outline principles and instances of best practice for licence agreements, particularly the use of non-exclusive licences.[508] The guidelines provide a template to help frame balanced and acceptable licensing terms when there are competing interests or inequity in terms of bargaining power. They outline key considerations that licensing agreements should address, such as encouraging rapid dissemination of information, fostering innovation, ensuring opportunities for all parties to obtain returns and providing certainty over the scope of the licence, the rights associated with the technology and the ownership of rights arising from any research using the technology. In addition, they suggest a variety of approaches to the payment of royalties that take into account the financial burden falling on the licensee over the lifetime of the licence. The widespread use of non-exclusive licences which utilise the principles and best practices outlined in the OECD report should be encouraged in the area of biofuels. The recommendation that continuous monitoring of practices and a stronger economic evidence base for the impact of IPRs should also be adopted.

506 Doha Declaration of 2001 G-77/SS/2005/1.
507 Agreement of Trade Related Aspects of Intellectual Property Rights of 1994, art 31b.
508 Organisation for Economic Co-operation and Development (2006) *Guidelines for the licensing of genetic inventions*, available at: http://www.oecd.org/dataoecd/39/38/36198812.pdf.

5.75 A more recent report suggests that the challenges do not lie with IP alone. In *Patents and Clean Energy*,[509] many companies involved in clean energy technology were described as willing to offer more flexible licensing terms (including monetary ones) to entities based in developing countries but did not do so owing to a number of factors such as transaction costs, challenges in identifying a suitable partner and mutually agreed licensing conditions (i.e. pricing and the geographical or exclusive scope of the agreement), and other market conditions.

5.76 The exercise of IPRs through an array of licensing practices can not only provide rights holders with the ability to achieve a return on their investment but also ensure and encourage access to these inventions. While there is no optimum single model for licensing, the environment and manner in which rights holders choose to carry out such activities has and will increasingly have implications for future research, development, access and dissemination of biofuels-related technology. The ethical responsibility with which these practices are approached can be better discharged by considering how far and how well draft licensing agreements reflect the core principles of this report.

Challenges for the future: the sharing of knowledge – research exemption

5.77 The freedom to pursue scientific research and to enjoy the benefits of scientific progress are explicitly recognised as human rights.[510] Where these conflict with IPRs, it raises questions about how well existing systems strike an appropriate balance.

5.78 Advanced plant breeding strategies, such as those described in Chapter 3, may lead to the development of new plant varieties which can be protected by plant variety rights. The plant variety rights regime meets our requirements for Principle 4, in that it provides a reward for innovation but permits access to the result of that innovation.

5.79 One of the cornerstones of a plant variety rights system is the breeders' exemption.[511] The exemption allows breeders to use protected material for the purpose of breeding other varieties without the authorisation of the plant variety right holder. This exemption was included because it was considered in the public interest to allow breeders free access to plant material in order to breed new varieties. Where this research leads to a new variety, the breeder of the new variety can claim rights over it without having to obtain permission from the first breeder. The exception to this exemption is where the new variety is considered to be an essentially derived variety.

5.80 This is not the case under patent law. The right to use patented material for research purposes only applies where those acts are regarded as private, non-commercial use and experimental. The interpretation of the research exemption is notoriously uneven between countries although the tendency is towards a very narrow construction; generally speaking, any research for commercial purposes will be seen as infringing the patent. Accordingly, patent law does not permit the same level of access to knowledge and products as seen under the plant variety rights provisions.

5.81 In France and Germany, the breeders' exemption from plant variety law has been integrated into patent law via the research exemption allowing the use of biological material for the purpose of breeding, discovering and developing a new plant variety.[512] The Netherlands is soon to adopt the same approach. The introduction of the breeders' exemption into UK patent law would go some way to striking the balance required by Principle 4.

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[509] United Nations (2010) *Patents and clean energy: bridging the gap between evidence and policy – final report*, available at: http://www.epo.org/topics/issues/clean-energy/study.html.

[510] International Covenant on Economic, Social and Cultural Rights of 1966, art 15.

[511] International Convention for the Protection of New Varieties of Plants of 1991, art 15.

[512] Unlike the breeders' exemption, however, it does not extend to the subsequent commercial use. Thus, a new plant or plant variety that still possesses the specific characteristics of the patented plant can only be brought to market after a licence has been obtained. If the patent holder is unwilling to grant a licence, the breeder may obtain a compulsory licence under the condition that the patent holder is entitled to a cross-licence on the protected variety.

Recommendations

5.82 **We recommend the drafting and adoption by the UK Intellectual Property Office of a licensing scheme and a framework of biofuels principles and best practices along the lines of the Organisation for Economic Co-operation and Development guidelines.**

5.83 **We recommend increasing the availability of licensing arrangements with respect to biofuels technologies and more research on the economic and social impacts of intellectual property in these fields.**

5.84 **We recommend to the UK Department for Business, Innovation and Skills and the Intellectual Property Office the introduction of the breeders' exemption into UK patent law.**

Principle 5: Equitable distribution of costs and benefits

Costs and benefits of biofuels should be distributed in an equitable way

> **"Since the private sector is much weaker in developing countries than in developed, the governments in developing countries should particularly stimulate public-private partnerships"**[513]

> **"A recent study from Tanzania [IIED (2009) *Biofuels, Land Access and Rural Livelihoods in Tanzania*], for example, shows that with due recognition of local contexts biofuel companies using out grower and other contracted smallholder arrangements have little direct negative impacts on land access and represent a more positive model for the environment and local livelihoods…Foreign firms can contract local small farmers to grow crops for them, providing farmers with more security and predictability than from simply selling crops on open markets."**[514]

5.85 Developing policies to ensure that the costs and benefits of biofuels are distributed in an equitable way is not straightforward. First of all, it is important to note that costs and benefits relevant to equity extend well beyond purely financial losses or revenue. The costs and benefits of biofuels production may be complex and interrelated and accumulate in different ways in different contexts. For example, depending on how one chooses to model GHG emissions, climate change mitigation benefits may accrue immediately, several hundred years from now, or not at all. One must also make distinctions between benefits that might be described as public goods and benefits which may accrue to only certain segments of society in certain parts of the world – a sufficient supply of liquid transport fuel is one example.

5.86 As laid out in Chapter 4, there are strong reasons to consider the reduction of GHG emissions as a benefit and reducing the rate of global warming may be described as a common good. The specific benefit of this common good, however, needs to be offset against the burdens on some segments of society to enable this to happen. For example, investment in biofuels to reduce GHG emissions may lead to food insecurity or pose livelihood implications for only certain, invariably poorer or more vulnerable, parts of society (see Principle 1).

5.87 The inherent complexity of global biofuels value chains and uncertainty about their impacts make it difficult to develop universal policy aimed at shared costs and benefits. Many agro-food systems and global value chains share costs and benefits in broadly similar ways: risks are generally disproportionately borne by the basic feedstock producer due to the institutional arrangements that govern the relationships in the chain. The power to shape these institutional arrangements is usually held further along the chain away from the locus of production, and this power has been progressively strengthened as particular actors, supermarkets for example, gain control over more elements of the chain.

513 International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), responding to the Working Party's consultation.
514 Dr Thomas Molony, Centre of African Studies, University of Edinburgh, responding to the Working Party's consultation.

5.88 Costs and benefits may range from proximate to structural, and from environmental to political, social or economic, and there will invariably be trade-offs in conceptualising policy that aims to distribute costs and benefits equitably. It is more realistic to aim to ensure that policy concerned with the common good aims broadly to maximise benefits and reduce costs, while ensuring that additional inequities are not created in an already inequitable world.

Biofuel-specific policies

5.89 Although the RED endeavours to address most of our Principles discussed so far in some – albeit sometimes inadequate – way, the issue of equitable cost–benefit distribution is not specifically included. Moreover, Principle 5 is the only one of our Principles which is not, in some specific way, addressed in initiatives to develop and establish biofuels sustainability standards and certification mentioned above. This is surprising since most issues discussed in this chapter could also be framed in terms of costs, benefits and equity.

5.90 The RED and other policies incentivising biofuels production have potential impacts that could lead to violations of equity in cost–benefit distribution. For example, if a developing country invests heavily in slow-growing feedstocks such as jatropha, which has been heralded to help fulfil GHG emissions savings requirements, and these are then superseded or deemed less important through changes in policy, the country could incur significant costs that are not captured by current policies.[515] Developing countries and their farmers will be ill-equipped to become competitive quickly in other land use activities or by using other forms of biofuels production. Moreover, some of the new biofuels promoted through the RED may remove a comparative advantage of many developing countries, i.e. that those located in the tropics they can produce biomass more quickly and efficiently. New biofuels, such as those discussed in Chapter 3, may rely on advanced technologies to which developing countries may not have access. Policies need to ensure that new technologies and innovations are readily available to all and this will require the involvement of developing countries in the actual development of these technologies.

Challenges for the future: international setting

5.91 One of the key challenges for policies designed to support equitable cost–benefit sharing is the current skewed distribution of power, resources, resilience and options that characterises global agricultural (and other) production chains. These shape different goals, aspirations and interests so that it will be impossible to develop policies that will not face opposition or require trade-offs that are unpalatable to some stakeholders. Powerful interests will strive to ensure that negative impacts affect those who are relatively powerless. For example, a system where industry consolidates agricultural land to grow biofuels feedstocks in Indonesia benefits fewer people than would be the case for smallholder-led cultivation on the same parcel of land. It is, however, difficult to develop policies to intervene equitably in this scenario as there may be economies of scale in commercialising agricultural production (for example, around jatropha production) that offset the disadvantages of placing production and profits in the hands of relatively fewer people.

5.92 Multiple trade-offs between different costs and benefits and the people they impact upon, some of which are little understood or not yet identified, mean that policy will invariably generate inequities unless it is itself similarly complex and nuanced. There are very few examples of policies avoiding such consequences entirely. The RED aims to generate European benefits, reducing GHG emissions without seriously impacting on the energy consumption and lifestyle patterns of European citizens. It does not aim to give equal weight to the implications within the countries that produce feedstocks and biofuels for that market. At best, there could be indirect implications for economic equity through biofuels pricing which could be promoted by the RED.

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[515] To some degree, this is also true for perennial biomass crops such as willow, poplar, miscanthus and switchgrass which take approximately four years before yields are obtained.

5.93 A key concern regarding the equitable international distribution of biofuels benefits is to ensure appropriate management of global versus local production. As a global market in feedstocks and biofuels develops, it is likely that commodities will be drawn towards developed regions of the world to meet their populations' needs. There are many examples of successful, small-scale, local biofuels initiatives that provide energy, income and livelihoods in fuel-poor locales not connected to mains electricity, for example in rural Mali,[516] and these examples of positive developmental impacts may be lost if policies are geared to the internationalisation of biofuels markets as in the RED's targets. Policies that encourage biofuels production therefore need to balance production for local needs and production for international markets.

5.94 Policies that encourage the development and adoption of appropriate technologies, for example small-scale biorefineries, are relevant in many contexts. National and international policies focused on energy security and lowering GHG emissions should include mechanisms to encourage local biofuels production and consumption where this is helpful, serving local needs as well as serving the needs of the developed world. Likewise, policies are needed that encourage smallholder and outcropper production of feedstocks in a sustainable way, particularly in developing countries which suffer from fuel poverty. Policies should recognise that, while there may be economies of scale and efficiencies in commercialising and centralising feedstock production, this can sometimes limit local livelihood benefits. The relatively high cost of processing encourages centralised production, but encouraging the development of, for example, small-scale biorefineries can encourage smallholders to derive income from feedstock production, delivering many additional local benefits that are not recognised in global equations. Echoing some thoughts expressed in the introduction to this chapter, it is also important to recognise that policies aimed to ensure sustainable industrial production, such as, for example, certification, have to be wielded with care, lest they impose inappropriate 'red tape'. Where local small-scale production serves important needs, such as providing energy which would otherwise not be available, certification should allow for exceptions in order not to stifle such essential production and disadvantage small-scale producers in poor countries. (Of course, biofuels for export, for example into the EU, would always need to adhere to international certification.)

5.95 Similar thoughts can moreover apply to the developed world: a decentralised model of refining where a refinery works with local networks of feedstock suppliers could have infrastructural advantages of flexibility in the UK and should not be discouraged.

Challenges for the future: public–private partnerships and product-development partnerships

5.96 Public–private partnerships (PPPs) constitute one mechanism for risk sharing and developing technologies and products that correspond to the needs of a variety of stakeholders in developing countries as well as those in the EU and US. Another benefit-sharing model which could inform approaches to biofuels is the private/public product-development partnership (PDP) which has been successful in public health and healthcare, for example in drug development for HIV/AIDS or vaccines for malaria in developing countries. A very successful example of this is the public–private initiative to distribute HIV/AIDS medicines in Botswana.[517] Botswana, which has one of the highest HIV infection rates in the world, has seen active investment by its government into HIV research and drug development, mainly together with major international PPPs involving foreign donors. A well-known example of this is the African Comprehensive HIV/AIDS Partnership, which was established in 2000 between the Government

[516] Practical Action Consulting (2009) *Small-scale bioenergy initiatives: brief description and preliminary lessons on livelihood impacts from case studies in Asia, Latin America and Africa*, available at: ftp://ftp.fao.org/docrep/fao/011/aj991e/aj991e.pdf, pp51–5.

[517] Ramiah I and Reich MR (2005) Public-private partnerships and antiretroviral drugs for HIV/AIDS: lessons from Botswana *Health Affairs* **24**: 545–51.

of Botswana, the Bill & Melinda Gates Foundation and the Merck Company Foundation. With help from these and other partners, Botswana has established one of Africa's most comprehensive programmes of HIV/AIDS prevention and treatment. By 2008, more than 80 per cent of those in need were receiving treatment.[518]

5.97 It is important to acknowledge that such models are much less common in the area of energy technologies. Partnership approaches have been advocated by some developing countries during international climate change negotiations. For example, a network of Climate Innovation Centres has been suggested for India.[519] They have also been at the forefront of calls for compulsory licensing of some low carbon technologies – a suggestion that industrialised country governments and firms have strongly resisted. However, unlike in health care, there has not yet been significant agreement to implement such proposals. Some pilots of the Climate Innovation Centre concept are under way with funding from the UK Department for International Development.

5.98 Where they exist, these partnerships involve public–private interaction between sometimes multiple stakeholders, opening up new innovation pathways in areas where there are barriers to development such as market failures or lack of incentives for commercial development. They help to bridge the gaps between established institutions and actors to achieve what they cannot bring about in isolation, "building collective capacity to respond to turbulent conditions as creative solutions are needed that exceed the limited perspectives of each individual partner".[520]

5.99 With appropriate adaptation to local contexts and the policy areas involved in biofuels, such PPPs could be envisaged for biofuels. With biofuels, development faces the difficulty of integrating the interests of many international stakeholders from several sectors while protecting the environment as well as the interests of the poorer populations affected. Moreover, national and international policies intersect in biofuels development in many ways, for example agricultural policy, climate change policy and trade regulation, and PPPs could be a vehicle for developing biofuels in the interests of multiple stakeholders dealing with a complex institutional and organisational environment. Funding for biofuels is already distributed between public and private stakeholders (see Box 5.10), and this setting could be a launch pad for PDPs. However, it is important to acknowledge that progress so far in implementing arrangements of this nature for low carbon technologies – at least under the official umbrella of the United Nations (UN) Framework Convention on Climate Change – has been very limited, and there is much need for improvement.

Box 5.10: Public and public/private funding for biofuels: examples

BSBEC (UK)

- The BBSRC Sustainable Bioenergy Centre (BSBEC) brings together six research groups and 14 industrial partners. Funding totals £24 million, of which industrial partners contribute around £4 million, and the remainder comes from Research Councils UK.[521]

European Biofuels Technology Platform (EU)

- The European Biofuels Technology Platform proposed the creation of the European Industrial Bioenergy Initiative (EIBI), which has been launched in November 2010.[522]

[518] Republic of Botswana, Ministry of State President, National AIDS Coordinating Agency (2008) *2008 progress report of the national response to the UNGASS Declaration of Commitment on HIV/AIDS*, available at: http://www.unaids.org/en/dataanalysis/monitoringcountryprogress/2010progressreportssubmittedbycountries/2008progressreportssubmittedbycountries/botswana_2008_country_progress_report_en.pdf.

[519] Sagar AD, Bremner C and Grubb M (2009) Climate Innovation Centres: a partnership approach to meeting energy and climate challenges *Natural Resources Forum* **33**: 274–84.

[520] Saad M, Rowe K and James P (1999) Developing and sustaining effective partnerships through a high level of trust, in *Public and private sector partnerships: furthering development*, Montanheiro L, Haigh B, Morris D and Linehan M (Editors) (Sheffield: Sheffield Hallam University Press), p498.

[521] BBSRC Sustainable Bioenergy Centre (2010) *About us*, available at: http://www.bsbec.bbsrc.ac.uk/about/index.html.

- The EIBI would select and fund demonstration and/or reference plants projects, with a budget of €6–8 billion over 10 years. Both public and private research and development capability in the EU would be focused on achieving EU strategic objectives.
- The main outcomes would include developing EU use of sustainable biomass resources adjusted to local context, and stimulating education and training in the related scientific and technological areas.

Energy Biosciences Institute (US)

- The Energy Biosciences Institute (EBI) is working on the development of 'next-generation biofuels' (e.g. produced from dedicated energy crops), as well as various applications of biology to the energy sector.[523]
- EBI is a collaboration between the University of California, Berkeley, the Lawrence Berkeley National Laboratory, the University of Illinois at Urbana-Champaign and BP, which has committed to support the Institute with a 10-year, 500 million USD grant.

Recommendations

5.100 **We recommend that biofuels policy and future sustainability and certification initiatives should not discourage decentralised biofuels production, particularly in developing countries that suffer from fuel poverty.**

5.101 **Protection against the imposition of unfair costs on vulnerable populations should be developed and implemented.**

5.102 **Policy instruments, such as innovation incentives, bilateral agreements between the UK and other countries, and project funding, should be developed and implemented to ensure that benefits of biofuels production are shared equitably. This could, for example, be done through public–private or product-development partnerships. National instruments should be implemented with the help of governmental departments such as the UK Department for International Development and Department of Energy and Climate Change. International organisations such as the United Nations Framework Convention on Climate Change could oversee international schemes.**

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[522] European Biofuels Technology Platform (2010) *European Industrial Bioenergy Initiative (EIBI)*, available at: http://www.biofuelstp.eu/eibi.html.

[523] Energy Biosciences Institute (2010) *EBI at-a-glance*, available at: http://www.energybiosciencesinstitute.org/index.php?option=com_content&task=blogsection&id=2&Itemid=3.

General policy instruments

5.103 So far, we have looked at specific policies under each of the ethical principles. In addition to these biofuels-specific instruments, a wider policy background is relevant to meeting our Ethical Principles in biofuels systems. Many of these policies are international. They operate at different levels, have different status and interact in complex ways with national legislative systems. They include: guidelines for research and development; the World Trade Organization (WTO) law that includes environmental and trade standards; environmental sustainability and biodiversity standards; land law to protect property rights; formal schemes/practices (e.g. fair trade schemes); and direct innovation promotion policies. Some of these general policies can have problematic effects on biofuels development, while others – if enforced – could help to avoid some of the ethical problems. Below, we discuss some examples to illustrate the complexity of the general policy background for biofuels, and make some recommendations for improvement.

Guidelines for research and development

5.104 The oversight of research and development relevant to biofuels differs greatly internationally, and among the many fields involved, including, for example, agricultural science, climate science and biotechnology. Academic research in the UK will be covered by general ethical requirements but so far there is little in the way of ethical guidance on the various fields of research relevant to biofuels, despite the fact that research outcomes can be important elements in either causing or mitigating some of the ethical problems discussed in previous chapters and above. Existing academic ethical guidelines are probably sufficient for early-stage academic research where it is unclear what the basic research outcomes are going to be. However, once basic research outcomes have been clarified, i.e. at the development stage of proof-of-concept, our ethical framework could be used as a checklist or benchmark for considering whether a technology has the potential to violate one of our Ethical Principles. It is a challenging, forward-looking activity to try to assess the potential impacts of research outcomes on human rights, food security, the environment and GHG emissions, as well as effects on just reward and the fair allocation of benefits and harms. We believe, however, that such assessments will be increasingly necessary (see discussion in Chapter 6), and that they could aid the decision making of those stakeholders who take the technology towards further development and implementation (e.g. industry and governments). In the future, ethical impact assessment could become a requirement of larger research grants aimed at bringing technologies into wider commercial use.

5.105 **We recommend to research councils, funders and managers that work should be undertaken to evaluate the likely ethical effects of implementing particular biofuels technologies on a larger scale. This should happen at the stage of proof of concept. In the future, ethical impact assessment should become a requirement of larger research grants aimed at bringing technologies towards wider commercial use.**

WTO law

5.106 WTO law, insofar as it relates to the environmental sustainability of biofuels (Principle 2) (see Box 5.9), can make the application of policies designed to implement environmental sustainability standards for biofuels potentially difficult (see Box 5.11). Moreover, it is hard to predict whether and how current conflicts between trade law and sustainability standards will be resolved. Concerns about being accused of discrimination under WTO law may make some countries wary of applying strict sustainability standards. On the other hand, there exist measures within WTO law[524] that could be called upon in support of sustainability standards.

[524] General Agreement on Tariffs and Trade (GATT 1947).

Box 5.11: WTO law and biofuels

Two WTO agreements are pertinent to sustainability standards. The Agreement on Technical Barriers to Trade (TBT) deals specifically with mandatory technical regulations and voluntary standards, and the General Agreement on Tariffs and Trade (GATT) covers trade in goods. The TBT Agreement aims to ensure that standards do not result in barriers to international trade.[525] It prohibits discrimination against and between foreign products and the application of standards that are more trade restrictive than necessary. The GATT applies to a broader range of measures but contains similar rules.[526]

Discrimination can be said to occur if a member state makes a distinction between what are called "like products".[527]

It could be argued that different biofuels are "like products" even if manufactured through different processes, one being less sustainable than the other. Thus, in the course of applying Principle 2, member states could conceivably be infringing WTO law by refusing one biofuel over another. However, it is not clear whether different biofuels would be considered like or not.

Land use policy

5.107 A further important concern of relevance to the protection of human rights, the environment, climate change mitigation and the equitable distribution of relevant costs and benefits – and thus to almost all our Ethical Principles – are land use policies. Developing a coordinated approach to global land policy not only in relation to biofuels but also more generally is constrained by the principle of national sovereignty over resources, including land, enshrined in the core treaties of the Universal Declaration of Human Rights – the International Covenant on Civil and Political Rights[528] and the International Covenant on Economic, Social and Cultural Rights[529] – and principles of international law. Issues of land policy are sensitive even at the national scale, let alone internationally. Nonetheless, an international approach to land policy was laid out in Chapter 10 of Agenda 21, of the *Programme of action for sustainable development* agreed at the UN Conference on Environment and Development in Brazil in 1992. This chapter, entitled *Integrated approach to the planning and management of land resources*,[530] includes important aspects of land management proposed by the UN Commission on Sustainable Development (CSD).

5.108 In 2000, the CSD called for further government action on integrated land use planning to address, inter alia, issues of tenure and resolve competition among various domestic sectors for land resources.[531] However, this approach largely concentrates on *national* land use policy and seeks to promote equal access and rights to water and other natural and biological resources for all citizens (see Box 5.12).

Box 5.12: Reform of national land policy

Reform of national land policy is currently being promoted on the international development agenda. The African Union has issued a declaration on the need for work on land reform and has produced a fifth draft of a framework and guidance on land policy in Africa.[532] Further guidance on the importance of land reform for equitable development and poverty

525 Agreement on Technical Barriers to Trade.
526 General Agreement on Tariffs and Trade (GATT 1947). See also: World Trade Organization (2009) *Trade and climate change*, available at: http://www.wto.org/english/res_e/booksp_e/trade_climate_change_e.pdf.
527 World Trade Organization (2009) *Trade and climate change*, available at: http://www.wto.org/english/res_e/booksp_e/trade_climate_change_e.pdf, pp106ff.
528 International Covenant on Civil and Political Rights of 1966, art 1(2).
529 International Covenant on Economic, Social and Cultural Rights of 1966, art 1(2).
530 United Nations Development Programme (1992) *Integrated approach to the planning and management of land resources*, available at: http://www.unep.org/Documents.multilingual/Default.asp?DocumentID=52&ArticleID=58.
531 United Nations Economic and Social Council (2000) *Commission on Sustainable Development: report on the eighth session*, available at: http://www.un.org/documents/ecosoc/docs/2000/e2000-29.htm.
532 African Union (2009) *Declaration on land issues and challenges in Africa*, available at: http://www.unhabitat.org/downloads/docs/AssemblyDecisionLand.pdf; African Union, African Development Fund and Economic Commission for Africa (2008) *Land policy initiative: a framework to strengthen land rights, enhance productivity and secure livelihoods*, available at: http://www.uneca.org/sdd/events/land-policy/LandPolicyInitiative.pdf.

alleviation has also been produced recently by organisations such as the World Bank, the International Fund for Agricultural Development and the EU. All these institutions recognise that land policy reform needs to be undertaken in a transparent and participatory manner. Land use policy and planning are particularly complex as they involve balancing multiple objectives, multiple alternatives and multiple social interests and preferences.[533] To provide guidance on addressing these challenges, in 1997 the Food and Agriculture Organization of the United Nations (FAO) and UN Environment Programme outlined key issues and set out a strategy for change to assist governments in achieving integrated land management in the report *Negotiating a sustainable future for land*.[534] The FAO has also been working with national governments to build their national capacity to collect data to provide a basis for agro-ecological zoning.[535] The Brazilian agro-ecological zoning policy ZAE Cana, mentioned previously, is designed to restrict agricultural expansion to areas where it will have less environmental impact.[536]

5.109 As for the international context, mechanisms such as certification schemes and comprehensive LCAs that are able to account for different kinds of land use and could help to limit further land conversion are not yet available and are plagued with difficulties of implementation, measurement and monitoring. Despite these difficulties in influencing sustainable land use at the international level, the UN does recognise trans-boundary responsibilities of governments. It notes that governments have a responsibility to ensure that their actions do not cause damage to the environment of other states or to areas beyond national jurisdiction. So, this could potentially provide scope to work on aspects of global land policy. In reality, complex and lengthy negotiations will be required to agree a comprehensive and equitable approach that provides sufficient incentives to encourage implementation.

5.110 In the meantime, developing a harmonised approach to LCA and certification, and supporting fully integrated approaches to spatial planning at the national level that combine both agricultural and environmental aspects, will all begin to address the issue of ‘leakage’ of unsustainable practices into other areas of agriculture that would otherwise be addressed by internationally coordinated land policies. It is far beyond the remit of our report to make recommendations regarding international land use policies, but we return to this issue briefly in Chapter 6.

General international intellectual property instruments

5.111 The IP regime can play a role in ensuring that the costs and benefits associated with biofuels are distributed in an equitable way. This could be achieved by taking one of the key objectives of the Convention on Biological Diversity (CBD)[537] and integrating it into the IP regime. The most important requirement in the context of our Ethical Principles found within the CBD[538] is that of the fair and equitable sharing of the benefits arising from the use of genetic resources. The CBD articles on access and benefit sharing (ABS)[539] have been translated into the Bonn Guidelines on Access to Genetic Resources and the Fair and Equitable Sharing of the Benefits Arising out of their Utilization[540] (see Box 5.13). The UK has set up a competent national authority that is responsible for ABS arrangements and provides information on such

[533] Bantayan N and Bishop I (1998) Linking objective and subjective modelling for landuse decision making *Landscape and Urban Planning* **43**: 35–48.
[534] Food and Agriculture Organization of the United Nations and United Nations Environment Programme (1997) *Negotiating a sustainable future for land*, available at: http://www.fao.org/fileadmin/templates/nr/images/resources/pdf_documents/negotiat.pdf.
[535] For example, see: Food and Agriculture Organization of the United Nations (2011) *FAO Bioenergy and Food Security (BEFS) Project*, available at: http://www.fao.org/bioenergy/foodsecurity/befs/en/.
[536] Ministério da Agricultura, Pecuária e Abastecimento (2009) *Zonamento Agroecologico de Cana-de-Acucar*, English version available at: http://www.unica.com.br/downloads/sugarcane-agroecological-zoning.pdf.
[537] Convention on Biological Diversity of 1992. There are many other international instruments that can help build on the Principle, including but not limited to the International Convention for the Protection of New Varieties of Plants (UPOV Convention), the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGR) and the World Intellectual Property Organization (WIPO) instruments. It should be noted that none of these treaties or conventions are specifically aimed at IPRs *and* access and benefit sharing but contain elements that are relevant for an international regime.
[538] The CBD has three core objectives: the conservation of biological diversity; the sustainable use of the components of biological diversity; and the fair and equitable sharing of the benefits arising out of the use of genetic resources.
[539] Convention on Biological Diversity of 1992, art 8(j), 15, 16, 17, 19 and 20.
[540] The Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of the Benefits Arising out of Their Utilization of 2002.

arrangements within its jurisdiction.[541] However, so far policy has not brought about any changes within law, including IP law.[542]

Box 5.13: The Convention on Biological Diversity and the Bonn Guidelines

Article 15 of the CBD outlines the requirements for an access and benefit sharing (ABS) system, including those of prior informed consent and the fair and equitable sharing of benefits. However, there was little understanding of the meaning of these terms and the Article provided no detail on how to implement measures to fulfil these requirements in an effective and appropriate way.

After many years of discussion, the Bonn Guidelines – adopted by the parties to the CBD in 2002 – provide a flexible framework, setting out a series of aims, ideals or key features for the practical implementation of an ABS system. The guidelines can be used by contracting parties to introduce effective national legislation to fulfil the requirements for ABS. It could be argued that compliance with the CBD cannot be obtained until national legislation on ABS has been introduced.

The CBD requires a mechanism to facilitate access to plant material while the benefits arising from the utilisation of this material should be shared in a fair and equitable manner.[543] In order to bring this measure in line with Principle 4, a "share of the benefits arising from utilization" should be interpreted as meaning the sharing of benefit arising out of IPRs over the resource. The benefits that arise do not have to be monetary in nature but can include non-monetary benefits such as technology transfer and training projects.

The Bonn Guidelines, although not legally binding, suggest that countries take measures to encourage the disclosure of the country of origin of the genetic resources in applications for IPRs. This is relevant to biofuels particularly where material is sourced in developing countries. The requirement for the disclosure of origin of the genetic resources by those applying for patent protection could be one way of implementing the ABS provisions of the CBD and act as a mechanism to track compliance with these requirements.

5.112 Although the CBD and IP regimes may appear to have very different aims and objectives, many observers believe that the IP regime should support the objectives of the CBD, bringing a coherence to the interrelationship between these international agreements. A submission by the EC and its Member States in 2005[544] expressed the view that the disclosure of origin requirement for genetic resources should be applied to all patent applications. An obligation to disclose the country of origin of genetic resources in IPRs applications could help to trace future claims to access new knowledge or to share in its benefits. The Plant Varieties Act 1997 and the Community Plant Variety Right Regulation (EC/2100/94)[545] both contain a requirement to disclose the origin of the parents of a new variety and geographical origin of the variety itself.[546] There is no equivalent legal requirement in patent law, although some European countries, such as Belgium, have decided to implement the spirit of Recital 27 of the Biotechnology Directive,[547] which has had a similar effect.

[541] Department for Environment, Food and Rural Affairs (2009) *Genetic resources: access and benefit sharing*, available at: http://www.defra.gov.uk/environment/biodiversity/geneticresources/access.htm.

[542] The UK remains committed to the Ninth Conference of Parties' decision to implement an international regime on access and benefit sharing of genetic resources by the Tenth Conference of Parties in 2010, available at: www.cbd.int/doc/world/gb/gb-nr-04-en.doc.

[543] Equity in the CBD has been interpreted to mean unjust enrichment. Unjust enrichment is the principle that one person should not be able to take advantage unfairly of another's situation to earn a benefit that should belong, at least in part, to that other person. Equity law provides that unjust enrichment should lead to fair compensation.

[544] European Community and its Member States (2004) *Disclosure of origin or source of genetic resources and associated traditional knowledge in patent applications: proposal of the European Community and its Member States to WIPO*, available at: http://www.wipo.int/tk/en/genetic/proposals/european_community.pdf. The issue is being discussed again at the Third Intersessional Working Group in March 2011.

[545] Plant Varieties Act 1997; Council Regulation (EC) No 2100/94 of 27 July 1994 on Community plant variety rights [1994] OJ L 227/001.

[546] Section 4 of the Technical Questionnaire for a Community Plant Variety Right includes questions on the origin of the parents of a new variety and geographical origin of the variety itself. This requirement does not apply to all varieties.

[547] Directive 98/44/EC of the European Parliament and of the Council of 6 July 1998 on the legal protection of biotechnological inventions [1998] OJ L213/13, recital 27: "Whereas if an invention is based on biological material of plant or animal origin or if it uses such material, the patent application should, where appropriate, include information on the geographical origin of such material, if known; whereas this is without prejudice to the processing of patent applications or the validity of rights arising from granted patents."

5.113 The disclosure requirement would not affect the granting or enforceability of patents or the validity of rights arising from the patents. The aims of this provision are simply to contribute to transparency with regard to the geographical origin of the genetic source on which the invention is directly based, to help facilitate countries providing genetic resources to monitor compliance with regulations and contracts regarding access to and sharing of benefits from genetic resources, and to bring national policy in line with the Bonn Guidelines.[548] This could help the fair and equitable sharing of the benefits arising from the award of an IPR.

Challenges for the future: the UK and access and benefit sharing

5.114 Biofuels developments will use plants and plant genetic resources from outside the UK and the introduction of a disclosure of origin process in the patent application system in the UK would go some way to meeting the requirements of the equitable distribution of costs and benefits as required by Principle 5. The UK in its role as a competent national authority currently provides information for those seeking access to genetic resources and it also has a role in the monitoring, evaluation and enforcement of ABS agreements. This role could be expanded to include verification of the geographical origin of a resource in any relevant patent application. The competent national authority rather than patent examiners has the capacity required for verification of the information.

Challenges for the future: International access and benefit sharing

5.115 The above policy developments will only cover applicants (both domestic and foreign) seeking access to the UK's genetic resources. Therefore, they will not achieve the benefit-sharing objectives of the CBD internationally. Ensuring the equitable distribution of costs and benefits in biofuels development internationally will require, for example, an international protocol on ABS. In July 2010 at the Ninth Meeting of the *Ad Hoc* Open-ended Working Group on Access and Benefit-sharing of the CBD, agreement was reached on the text of a legally binding protocol on access to, and sharing of, the benefits from the use of genetic resources – the Nagoya Protocol. The draft protocol was finalised and adopted on 29 October 2010.[549] The Nagoya Protocol will open for signature by parties to the CBD from 2 February 2011. The UK should take the lead in ensuring the operation of such an effective global multilateral benefit-sharing mechanism. A successful ABS regime would allow developing countries, in particular, to exploit their genetic resources and reduce possible occurrences of misappropriation of those resources.

5.116 The Nagoya Protocol obliges members to establish clear rules and procedures for requiring and establishing mutually agreed terms on benefit sharing, including those in relation to IPRs. The UK could take a lead by linking the roles of the competent national authority on ABS with that of the IP office. The competent national authority, through the multilateral system, can raise awareness and facilitate access to material that can be used in the research and development of biofuels, while the UK Intellectual Property Office, which is already fast tracking green inventions through the patent system, can take a leading role in monitoring licensing agreements and commissioning research on the impacts of IPRs on technological development and access thereto.[550]

548 While it is the case in administrative terms that this option would only require a minor change in the law, there is a serious question about whether there is sufficient political will to bring about such a change. A more stringent version of the disclosure of origin, not recommended here, would make failure to disclose or dishonest disclosure result in either the patent application not being accepted or if granted not enforceable. This option would undoubtedly be met by universal opposition within the patent regimes.

549 Convention on Biological Diversity (2010) *A new era of living in harmony with nature is born at the Nagoya Biodiversity Summit,* available at: http://www.cbd.int/doc/press/2010/pr-2010-10-29-cop-10-en.pdf.

550 The UK Intellectual Property Office has assumed an active role in commissioning research and monitoring IP activity in recent years.

Recommendations

5.117 **We recommend to the UK Department for Business, Innovation and Skills and the Intellectual Property Office that the UK continues to promote compliance to access and benefit-sharing schemes by all users of genetic resources, including those employing them for the purposes of biofuels production.**

5.118 **We also recommend that a 'disclosure of origin' requirement be introduced into UK patent law to improve transparency about genetic resource use in order to facilitate access and benefit sharing.**

5.119 **We recommend that consideration be given to the introduction of a mandatory 'disclosure of origin of genetic resources' requirement in intellectual property law with appropriate sanctions, either outside or within patent law, for non- or incorrect disclosure.**

5.120 **We recommend that the UK updates current access and benefit-sharing arrangements to take account of the legislative, administrative and policy measures introduced in the Nagoya Protocol on Access and Benefit Sharing. This process could be overseen by the UK Department for International Development and should be integrated into more specific biofuels polices, such as a sustainability standard and certification scheme.**

5.121 **We recommend to the UK Department for International Development that the UK should take the lead in giving support to developing countries to set up competent national authorities on access and benefit sharing and in providing advice on the practical implementation of the requirements of the Nagoya Protocol and Bonn Guidelines.**

5.122 **We recommend that international organisations such as the World Trade Organization and the World Intellectual Property Organization look into the feasibility of integrating the key concepts of the Convention on Biological Diversity into intellectual property law. This may lessen the adverse impact that the Trade Related Aspects of Intellectual Property Rights Agreement has had on developing countries.**

Summary

5.123 This chapter has demonstrated how individual elements of the policy environment act either to support or to challenge the application of our Ethical Principles 1–5 in the development of biofuels, and has made recommendations on how modifications could be introduced to help meet the requirements of these Principles. The interacting elements of the complex international system behind the development and use of biofuels include: public and commercial users of fuels; researchers in public institutions and commercial laboratories developing improvements to existing biofuels and radically new approaches to biofuels developments; NGOs often with principled views on biofuels; farmers in the developing and developed world; industry ranging from small companies to large multinationals; national and international regulatory systems; and governments and policy makers. We have not yet addressed Principle 6 – a potential duty to develop biofuels – in this chapter, but we turn to it in Chapter 6. There, we open up the debate beyond the biofuels context.

Chapter 6

Biofuels and the bigger picture

Chapter 6 – Biofuels and the bigger picture

Introduction

6.1 The core of the ethical framework developed in this report is formed by a set of six Ethical Principles, the first five of which are prior requirements to be met in biofuels developments. In the previous chapter, we examined some biofuel-specific policies and made recommendations as to how these should be improved in keeping with the first five Ethical Principles. It is unlikely that a biofuel will meet all of our Ethical Principles to the desired extent just like that. Indeed, there are bound to be many cases where the need to meet the demands of one principle will conflict with the ability to meet the demands of another. Carefully designed policy is necessary to manage such conflicts in practice and to make sure that meeting one principle does not unduly compromise meeting the demands of others – a challenge to policy makers attempting to put our previous recommendations into practice.

6.2 In this chapter, turning to our final Ethical Principle, Principle 6, we take a step back from these specific policy issues related to biofuels. Principle 6 asks a broader question: Could there be a duty to develop biofuels once the other principles are met? This question cannot be answered without relocating the issues to a wider environment, both in policy terms as well as in terms of alternative technologies.

6.3 We start by looking at some broader questions which partly arise from our recommendations in Chapter 5, for example regarding the development of new biofuels through the use of biotechnologies. We then proceed to apply Principle 6. How could a duty to develop biofuels arise, and, in light of other pressures on public and private finances, which aspects need to be considered so that consistent and coherent decision making can be established? Answers to these questions cannot be given by recourse to biofuels alone, and Principle 6 therefore enjoins us to consider other, alternative technologies. In this chapter we thus sketch out how our ethical framework could be applied to other technologies and other related policy areas.

Biofuels and the 'perfect storm'

6.4 Chapter 1 of this report described the powerful drivers that have influenced investment in biofuel-related technologies:

- energy and fuel security;
- economic development; and
- climate change mitigation.

These motives catalysed policies that led to very rapid adoption of a limited range of approaches to biofuels development, which in turn resulted in negative impacts, some of which have arguably exacerbated rather than alleviated the problems that biofuels are intended to address. For example, direct and indirect land use change may contribute negatively to climate change and confound the sustainability of economic development.

6.5 The use of food crops and of land previously devoted to growing food crops for the production of biofuels was one factor linked to a rise in food prices, triggering the so-called 'food versus fuel' debate. However, other factors also contributed to food shortages, including yield instability due to extreme weather events, financial speculation and increased meat consumption in rapidly developing parts of the world. These factors form components of the 'perfect storm', which was described as follows by Sir John Beddington, the UK Government's Chief Scientific Adviser:

"The growing global population coming out of poverty will create an increased demand for food which will need to be produced on not much more land, using less water, fertiliser and pesticides than we have historically done. Through the 21st century this is achievable, but must be tackled coherently with other global challenges of climate change and energy, food and water security. It is predicted that by 2030 the world will need to produce around 50 per cent more food and energy, together with 30 per cent more fresh water, while mitigating and adapting to climate change."[551]

6.6 Sir John goes on to pose four key challenges for policy makers and scientists:

- Can 9 billion people be fed equitably, healthily and sustainably?
- Can we cope with the future demands on water?
- Can we provide enough energy to supply the growing population coming out of poverty?
- Can we do all this while mitigating and adapting to climate change?

6.7 All four of these formidable challenges – plus the challenge of protecting basic human rights and maintaining ecosystem services – are linked in some way to the development of biofuels, as described in earlier chapters. Indeed, biofuels occupy a space where almost all the big challenges the world faces today converge. Because of the complexity and interrelatedness of these challenges, it is not possible to find optimal solutions by changing only one of the numerous variables that contribute to them, neither with regard to the underlying issues nor with regard to biofuels technologies. The key is to find combinations of policy and technology levers that can stimulate systemic shifts in orientation, profoundly altering the opportunities for biofuels developments and minimising their impacts on people and the environment.

6.8 Professor Raphie Kaplinsky of the Open University, UK, makes the point that in recent centuries the dominant source of technological innovation has been the US, Europe and a small group of predominantly north-east Asian middle- and high-income countries. He says: "Not surprisingly, this context for innovation and growth has led to an innovation trajectory...which increasingly favours the use of labour-saving technological progress, assumes high-quality and pervasive infrastructure and produces products for high-income consumers at a large scale."[552] He notes, however, the increasing role played by China and India in innovation and asks whether the different social technologies and institutional environments in these countries might result in different innovation trajectories.

6.9 We recognise the complexity of innovation patterns in the fossil fuel and biofuels industries and the powerful forces ranged against any major changes to the status quo. An important component of this resistance to change is the lock-in to current fuel production and distribution systems, with their associated investment in major facilities worldwide. In these circumstances, radical change is inevitably disruptive and can lead to unanticipated effects that are more damaging than the system being replaced, often resulting in apparently conservative policy approaches. The challenge becomes one of enabling change in a way that is flexible enough to allow adaptation if needed and at the same time powerful enough to shift current production systems.

6.10 We believe that there is a significant role for biofuels to contribute to some dimensions of energy security, in particular in the transport sector, as well as climate change mitigation by reducing fossil fuel consumption, particularly given the new scientific advances highlighted in Chapter 3

[551] John Beddington (2010) *Food, energy, water and the climate: a perfect storm of global events?*, available at: http://www.bis.gov.uk/assets/bispartners/goscience/docs/p/perfect-storm-paper.pdf.

[552] Kaplinsky R (2011) Schumacher meets Schumpeter: appropriate technology below the radar *Research Policy* **40**: 193–203.

(the hurdles to fulfilling this role have been described in earlier chapters under the first five of our Ethical Principles). The basis for this assessment is the energy available in biomass and the likelihood of being able to access it within a relatively short timescale. This is coupled with the medium-term requirement for transitional technologies that can work with current infrastructure to deliver renewable transport fuels during the transition to future more effective solutions, and a recognition of the likely longer term requirement for some liquid transport fuel for aviation and heavy goods haulage.

6.11 It is important to recognise that there remains uncertainty about the extent of the potential contribution of biofuels to climate change mitigation, the time frame within which it can be delivered, and the feasibility of alternative non-biofuels technologies that might contribute more effectively to resolving the problem. However, biofuels have an impressive potential range of production scales in that they can contribute on a national scale as seen in Brazil, as well as through small-scale local schemes. Thus, there are strong reasons to support biofuels developments that will, given an appropriate policy environment, comply with our Ethical Principles.

6.12 However, developing this appropriate policy environment will not be straightforward. There is a need to balance flexibility to incorporate new evidence and avoid lock-in to sub-optimal approaches against the stability required to encourage investment and support for longer term changes in energy supply systems. The benefits of stability include: a predictable, long-term policy strategy and consistent and clear regulation for industry and farmers; stable incomes; and a strong basis for decision making on investment and company strategy. On the other hand, the benefits of flexibility include: avoiding lock-in to inferior technology pathways; and enabling new development pathways to be built up so that new scientific discoveries can contribute on a level playing field to future expansion in biofuels use.

Some general considerations

The best use of current biofuels resources

6.13 This report has pointed to numerous ethical problems raised by current biofuels systems. However, as some mandatory policy is already in place, the current generation of biofuels technologies will continue to be used for some time. It is therefore important to achieve the best possible use of current biofuels resources. Choices among alternative technologies – bioethanol or biobutanol; sugar cane or corn? – carry important implications in a resource/money-constrained world and, in addition to ethical considerations, they should be based on a clear, explicit and logical approach.

6.14 There are many methods available for selecting between different technological options within the policy context. These methods usually rely on various criteria, some of which are explicit while others are implicit or simply not stated. In keeping with our ethical framework, we urge that all relevant criteria should be openly specified, so that decision making, which attempts to determine the 'best use' of resources such as biomass generally or biofuels specifically, is objective and transparent. One approach which has been increasingly used in UK Government departments has been the use of 'resource cost curves'. In the context of choosing options for mitigating global climate change, the criterion (or indicator) adopted has been net greenhouse gas (GHG) emissions savings per GBP invested or spent. This covers just one of the five dimensions captured in our Ethical Principles, but, of course, other criteria are possible.[553] The attraction of resource cost curves is that they not only show the relative cost of, for example, saving "one tonne of carbon" but also combine this with the magnitude of net savings that can be achieved by each option.

[553] Other criteria and approaches exist and have been applied elsewhere to the problem of determining the best use of biomass and biofuels resources; see, for example, work on this problem in Denmark in: Wenzel H (2010) *Breaking the biomass bottleneck of the fossil free society*, available at: http://www.concito.info/upload/arkiv_55_1791740804.pdf.

6.15 Such cost curves are helpful in decision making and they could serve as a model for a tool that captures elements of the evaluation in a transparent way. However, they do not make careful consideration and judgment superfluous. On the contrary, decisions cannot be left to simple mathematical calculations and models; they require judgments to be made on the balance of evidence and arguments that capture interrelated and complex dimensions, such as social and environmental impacts. We therefore urge investors and policy makers to refer to our Ethical Principles when assessing alternative biofuels options and to make their reasoning as explicit and transparent as possible.

Developing and encouraging new approaches to biofuels

6.16 As we have shown in Chapter 2, current biofuels production brings with it several ethical challenges. Chapter 3 gave a glimpse into the dynamic field of new biofuels development which tries to respond to these challenges. Major research activities are under way to find a technology that is successful regarding climate change mitigation, sustainable production, scalability and economic appeal. The field warrants some optimism: given sufficient encouragement, one or several of the new approaches could mature into a commercially attractive as well as ethically acceptable option.

6.17 However, there is a big discrepancy between the powerful targets and related penalties that are in place for currently used biofuels and the very few incentives or governance approaches for new technological methods for developing biofuels that would stand a better chance of complying with our Ethical Principles. For example, there are no technology incentives in the Renewable Energy Directive (RED) or Renewable Transport Fuels Obligations (RTFO) even though new technologies from several research directions, including biotechnologies for genetic improvement, may be among the best options to mitigate global climate change through development of biofuels technologies that comply with our Ethical Principles.

6.18 While we have argued in this report that none of the new approaches is perfect and each is associated with inherent uncertainty, we take the view that it is important to recognise their potential positive attributes. Dismissal of this potential based on avoidable problems would be to 'throw out the baby with the bath water'.

6.19 Box 6.1 presents the three approaches we have discussed in Chapter 3 as scenarios. These scenarios are deliberately positive – i.e. whereby the technologies could achieve our main objective in that they have the potential to comply with our Ethical Principles, and practical challenges or tensions with at least some of our Ethical Principles are avoidable, for example through governance-related safeguards and optimum development of infrastructure. The scenarios are illustrative; we use them here as examples of how we can look at production options in the light of ethical considerations and design processes accordingly. From our previous discussions it is also clear that, even if they deliver, they cannot be applied in all regions and in all contexts. Thus, they should also be taken as illustrations of which elements we could use in a future *mix* of biofuels options.

Box 6.1: Three potential positive scenarios

Biofuels from residues

Production of lignocellulosic biofuels from agricultural residues left over from food crops presents several potential advantages from the perspective of the first five Ethical Principles. It is difficult to envisage how use of residues might impinge on people's essential rights that are described in Principle 1 (health, well-being, food and water security, and land entitlement); indeed, use of such residues could limit the amount going to landfill which is itself associated with pollution and adverse health impacts – a contribution to satisfying Principle 2 (environmental sustainability). Since no additional land other than the land used for the production of the original food crops is required, there would be no greenhouse gas (GHG) emissions from land use change for biofuels production. Furthermore, there is a significant opportunity for domestic production of lignocellulosic biofuels from agricultural residues, and also local small-scale production given the advent of decentralised production facilities. This too would help in delivering net reductions in GHG emissions and avoiding contributions to climate change as required by Principle 3 through a reduced need for transporting residues. Novel biotechnological approaches, including genetic modification, are expected to improve digestibility of lignocellulose and to deliver significant cost reductions and improved efficiency in future commercial applications.

Since this is still a developing approach to biofuels production,[554] it would be possible to steer industry so as to comply with comprehensive sustainability standards and trade principles that are fair, and to ensure the equitable distribution of costs and rewards between stakeholders – for example by supporting local production of biofuels from residues and waste.

Biofuels from dedicated energy crops

The use of dedicated energy crops for biofuels production could also fare well against our Ethical Principles. Perennial crops potentially have high energy-conversion ratios – i.e. high yield with minimum inputs – which is a crucial characteristic for a biofuels feedstock. There is potential for developments in this area to diversify the agricultural landscape by introducing different types of plant and entirely different cropping systems. The different cropping systems will benefit biodiversity as well as decrease erosion and run-off, supporting Principle 2, and could provide options of new and more sustainable, diverse agro-ecosystems. The use of advanced plant breeding or genetic modification techniques could furthermore enhance traits via the ability to develop crops with maximised yields per area of land and reduced fertiliser, pesticide and water requirements. Such developments would deliver additional GHG emissions savings, satisfying Principle 3. If successful, they would also reduce the need for agricultural resources such as fertile land and water that are usually required for growth of food crops, thus sidestepping harmful impacts on food security. A reduced need for water would also help avoid threats to water security. All of this contributes to meeting the requirements of Principle 1. The developments that increase the energy-conversion efficiency of plants could help achieve environmental sustainability and GHG emissions savings for this method of biofuels production, satisfying Principles 2 and 3. Other aims of advanced plant breeding or genetic improvement approaches include improved ease of harvesting and storage and enhanced suitability for processing (an aim that could also be achieved through the development of genetically modified microbes), and these too would help to contribute to the overall environmental sustainability of this method of biofuels production (Principle 2).

Again, as this is a nascent industry, there are opportunities for regulation that would help to ensure protection against human rights violations, and enable just reward and equitable distribution of costs and benefits, for example through benefit-sharing schemes. A transition of this currently high-tech and high-cost technology to a routine processing approach could be helped by public–private partnerships or, within programmes of development aid, by enabling poorer countries to gain access to the novel technologies. Again, it will be important to ensure that comprehensive sustainability and social standards are in place.

Biofuels from algae

The potential to improve biofuel yields from algae is significant owing to the great genetic variety of the source material. Biotechnological options (including synthetic biology) are proposed to be able to deliver the necessary improvement in relevant traits, although estimates of the necessary timescale vary from five to 20 years. Higher biofuel yields – genetically modified or otherwise – would impact favourably on environmental sustainability, as demanded by Principle 2, given appropriate safeguards against the risks that may be entailed in any novel technological approach. Algal-based biofuels production is still in its infancy and therefore, again, there is the chance to develop production facilities designed with environmental and social sustainability in mind. For example, plants could be positioned near a power plant and/or water-cleaning works since algae are able to use wastewater as a source of nutrients and combustion gas as a carbon dioxide source. In addition, algae produce a variety of fuels and co-products, making them highly suitable for incorporation in a biorefinery model, contributing to environmental sustainability and net GHG emissions savings, supporting Principle 3. Algae would require a land base on which to site production facilities but there is no need for this to be fertile land: indirect threats to food security through land competition would thus be reduced. As with the previous approaches outlined, the early stage of development of the industry could enable appropriate safeguards to be incorporated to satisfy Ethical Principles 4 and 5. Particularly relevant here would be regulations to protect the right to just reward, including covering intellectual property as it relates to algal species.

To satisfy our ethical framework, the fast-growing algae industry needs ethical safeguards incorporating our Ethical Principles. In particular, these should try to ensure that any benefits that do materialise strike an appropriate balance between equitable cost–benefit sharing and justified profit by those who invested in algal research and development. Access and benefit-sharing schemes will be central to achieving this balance.

6.20 **We recommend to research councils that specific policies be developed and implemented that directly incentivise research and development of new and emerging biofuels technologies that need less land and other resources, avoid social and environmental harms in production, and deliver significant greenhouse gas emissions savings.**

[554] Some countries, for example Germany, have been producing biofuels from agricultural residues for some time now, but in most other countries this is still a new approach.

Using modern biotechnology

6.21 As these three scenarios show, using modern biotechnology to improve crops and feedstocks is a potentially productive option to enable the development of biofuels that could directly and positively contribute to Principles 1 (human rights), 2 (environmental sustainability) and 3 (climate change). There are also expected benefits from the use of genetic technologies to produce improved or cheaper enzymes to enhance the efficiency of digestion of lignocellulosic biomass. For example, both yeasts and bacteria are being genetically modified to improve fermentation of biomass while withstanding high ethanol concentrations, which increase as the fermentation process proceeds. Alternative approaches aim to develop microorganisms that enable sidestepping the expensive and energy-intensive step of distillation; other examples are using genetically modified microbes to produce biodiesel from sugars or from syngas. Technologies for genetic improvement, including advanced plant breeding strategies and other process-based approaches, have the potential to contribute to mitigating global climate change, to meet the practical challenges addressed in this chapter, to comply with the demands of our Ethical Principles, and to alleviate some of the factors contributing to the 'perfect storm'. However, it is important to consider the cost–benefit relationship using a transparent,[555] evidence-based approach for each proposed technology-based system.

Proportionate regulation for modern biotechnology

6.22 A proportionate risk governance approach for innovative technology has been described as symmetrical to the risks and benefits to individuals and society, allowing for different applications depending on the context.[556] It should be evidence-based, enabling of innovation, minimising risk to people and the environment, and balancing the interests and values of all relevant stakeholders, avoiding simplistic comparisons across sectors and technologies.

6.23 By these standards, some argue that the governance system currently in place for genetically modified plants that could contribute to meeting our Ethical Principles is increasingly inappropriate. The European regulatory system for crops produced using genetic modification is more complex, time-consuming and expensive to implement than that for any other agriculture-related technology. There is evidence that crops produced using genetic modification do not carry any higher risks than those produced by other methods. For example, the effects of different herbicide regimes on insect biodiversity showed that the more effective the regime was in reducing weed diversity and numbers, the bigger the impact on insect biodiversity, regardless of whether the herbicide regime involved genetically modified herbicide-tolerant crops or conventional crops.[557] Indeed, there is evidence of the ability of genetically modified crops to contribute positively on balance to sustainable development, including economic, environmental and societal sustainability, although with some qualifications, as with all complex agricultural systems.[558]

6.24 A recent report from the UK Advisory Committee on Releases to the Environment, developed in response to the inconsistencies in the regulatory assessment of the environmental impact of genetically modified crops in comparison with other agricultural crops and practices, has

[555] This means, for example, that the data on which the decision for a particular biotechnology is made are publicly available and the chain of analysis can be replicated by others.

[556] Academy of Medical Sciences (2011) *A new pathway for the regulation and governance of health research*, available at: http://www.acmedsci.ac.uk/p99puid209.html.

[557] Farmscale Evaluations Research Committee and Scientific Steering Committee (2005) *Managing GM crops with herbicides: effects on farmland wildlife*, available at: http://webarchive.nationalarchives.gov.uk/20080306073937/http://www.defra.gov.uk/environment/gm/fse/results/fse-summary-05.pdf.

[558] Park TR, McFarlane I, Hartley Phipps H and Ceddia G (2011) The role of transgenic crops in sustainable development *Plant Biotechnology Journal* **9**: 2–21.

advocated proportionate comparative assessment of the risks and benefits of all novel agricultural systems, whether or not genetically modified crops are involved.[559]

6.25 In the context of biofuels development, regulatory systems are appropriately restrictive for what is called 'industrial biotechnology', for example where microorganisms such as algae are grown in contained conditions to produce biofuels. However, for plants grown outdoors, innovation is being restricted rather than enabled by the national and regional regulatory systems in force in Europe and increasingly in some other parts of the world, and particularly by the United Nations Convention on Biodiversity[560] and the associated Cartagena Protocol on Biosafety.[561] Although developed with the best of intentions at a time when there was much more uncertainty around the potential risks and benefits of genetically modified plants, these regulatory systems may no longer reflect recent evidence on risks in practice. These instruments could usefully be reviewed to assess whether and how they could contribute positively to the potential of modern biotechnology to meet the requirements of our Ethical Principles.

6.26 **We propose that, in order to address our Ethical Principles effectively, some modifications might be needed to existing policies and regulations related to new crop developments for agriculture and forestry. This might require some modifications to international agreements. Evidence-based and proportionate review of these policies should take place as soon as possible.**

Implementing Principle 6

6.27 Having looked at human rights, environmental sustainability, climate change, just reward and equitable cost–benefit distribution through Principles 1–5 and some general issues regarding the use of biomass and novel technologies, how do we determine whether there is a responsibility to develop biofuels? In today's world, is there an ethical duty to develop biofuels?

6.28 Our Principle 6 (Box 6.2) is proposed as a *duty not to do nothing*, to bring action forward, in cases where the other five Ethical Principles are either not violated or could be satisfied through appropriate governance mechanisms, *and* where (subject to the additional considerations) biofuels can enable us to fulfil our responsibility to mitigate climate change.

Box 6.2: Principle 6

If the first five Ethical Principles are respected and if biofuels can play a crucial role in mitigating dangerous climate change then, depending on additional key considerations, there is a duty to develop such biofuels.

These additional key considerations are:

- absolute cost consideration;
- alternative energy consideration;
- opportunity cost consideration;
- uncertainty consideration;
- irreversibility consideration;
- participation consideration; and
- proportionate governance consideration.

6.29 This is especially important in terms of the value of the common good. Reducing human-generated GHG emissions is in the long-term interests of those living now and those yet to be

[559] Advisory Committee on Releases to the Environment (2007) *Managing the footprint of agriculture: towards a comparative assessment of risks and benefits for novel agricultural systems*, available at: http://webarchive.nationalarchives.gov.uk/20080727101330/http://www.defra.gov.uk/environment/acre/fsewiderissues/pdf/acre-wi-final.pdf.

[560] Convention on Biological Diversity of 1992.

[561] Cartagena Protocol on Biosafety to the Convention on Biological Diversity of 2000.

born. Doing nothing offends directly against the common good. Reducing these emissions is not simply good stewardship, although that is important; it is a duty deriving from the common good.

6.30 A duty to develop biofuels that meet the standards of Ethical Principles 1–5 cannot be an unconditional one. Meeting the standards required by our first five Ethical Principles is but the first step in establishing whether a biofuels technology should become an ethical imperative and can be adopted widely. Principle 6 affirms that the existence of a duty depends on whether 'additional key considerations' are met. These relate to the efficient, effective and equitable use of resources and technology, and need to be assessed for any technology before it is considered for wide implementation:

- The 'absolute cost consideration' would rule out a development where the costs are out of all proportion to the benefits, compared to other major (public) spending priorities such as, for example, health or housing.
- The 'alternative energy sources consideration' would require investigations on whether there are competing energy sources that might be even better, for example at reducing GHG emissions, while still meeting all the required Ethical Principles.
- The 'opportunity cost consideration' would rule out a development where there is an alternative and better use of the biomass feedstock, for example as feedstock for higher value products from the chemical industry.
- The 'uncertainty consideration' would focus attention on the areas of uncertainty in the development and implementation of a technology, and incentivise efforts to reduce them.
- The 'irreversibility consideration' would help avoid the implementation of technologies that lead to irreversible consequences and damage, once they are scaled up. It would also contribute to evading the danger of a 'lock-in' to inferior technology solutions.
- The 'participation consideration' would ensure that fair attention is paid to the voices of those directly affected by the implementation of a technology.
- The overarching 'proportionate governance consideration' would rule out inflexible 'one size fits all' approaches to policy and make sure that policy instruments can be applied in a proportionate way symmetrical to the specific risks and benefits involved.

6.31 In relation to 'alternative and better uses' of biofuels themselves or of financial resources, it is important to bear in mind the urgency of the problem of global climate change and the need to use every available means to tackle it. From a policy and economic perspective, the question is not always "Do A or B?" but can also be "How can both A and B contribute together to mitigating global climate change?"

6.32 The practical parameters to be considered when assessing whether a biofuels technology meets these conditions are captured in a number of questions, for example:

- How effective is the biofuels technology – can production be scaled up sufficiently so that it makes a difference?
- What cost is involved – will the technology deliver a favourable return in a reasonable time frame?
- Is the potential for revenue big enough to interest industry stakeholders and investors?
- Can policy help to bridge the gap between the high-cost development stage and commercialisation, and if so how?

- What is the degree of uncertainty involved in the development and scaling up of this technology, and how could it be reduced?
- Will the implementation and scaling up of the technology result in irreversible consequences, and, if so, how could this be avoided?
- Have those directly affected been involved sufficiently in the decision-making process?
- Can policy instruments be applied in a proportionate way?

6.33 Answering these questions in the context of the considerations of Principle 6 should be part of a comprehensive comparative analysis of all different future energy and climate change abatement options, including comparison of energy *portfolios* with a different mix of technologies, since one technology might, for example, mitigate the disadvantages of another within a mix, or, instead, augment them. In fact, our ethical framework, as well as the questions we draw from them above, could serve as a template or a benchmark against which the ethical robustness of a range of possible pathways can be assessed. It could be a yardstick to hold up against a range of options to decide which is most appropriate in the future – a checklist of ethical appropriateness.

6.34 Moreover, this applies retrospectively as well. First and foremost, this template is, of course, about asking whether a particular technology should be pursued, but it is arguably equally valid to use the same template for ethical assessment of the governance mechanisms that are in place once it has been pursued and is being introduced and developed/implemented. Such evaluations across different technology pathways are challenging but are, we believe, necessary in order to make the complex comparisons between alternative technology options.

6.35 After careful consideration of all items on the checklist, going through Principles 1–5 and asking the questions which flow from Principle 6, we should be in a better position than we are today to make ethically based policy decisions. Put simply, if a technology, or a particular mix, meets our Ethical Principles 1–5 and has a positive evaluation under the additional considerations of Principle 6, then there is a duty to develop it.

6.36 **We suggest that UK and EU policy makers as well as those in the research community conduct comparative analysis of different energy portfolios rather than simply different technology options.**

6.37 **We encourage UK and EU policy makers undertaking comparative analyses of the impacts of different energy and climate change abatement technology options to apply our Ethical Principles 1–6 as a template or benchmark against which the ethical robustness of a range of possible pathways can be assessed when engaging in policy and technology appraisal.**

6.38 **If a biofuels technology, or a particular mix, meets all elements of our Ethical Principles 1–6 then there is a duty to develop it.**

An approach to support Ethical Principles 1–6

6.39 The systemic nature of the ‘perfect storm’ was outlined at the beginning of this chapter, and we have also emphasised the need for appropriately systemic responses, in particular seeing policy and governance approaches as necessary contributors to meeting the requirements of our Ethical Principles. To support effective policy making, we propose that these elements be seen as part of a coherent approach that incorporates these Ethical Principles alongside governance and regulatory components. Internationally traded products, based on contentious and sometimes unethical production processes in agriculture and forestry, have historically been resistant to policy-induced change, and it would be naïve to overestimate the power of one report to effect such change. Our aim here is to suggest an approach that brings together insights and recommendations based on our Ethical Principles, as a contribution to future policy decision making, nationally and internationally, in the expectation that it will reinforce other related initiatives and facilitate the desired changes.

6.40 Ideally, biofuel-specific instruments such as standards and certification would be embedded within wider policy instruments in international production and trade policy related to:

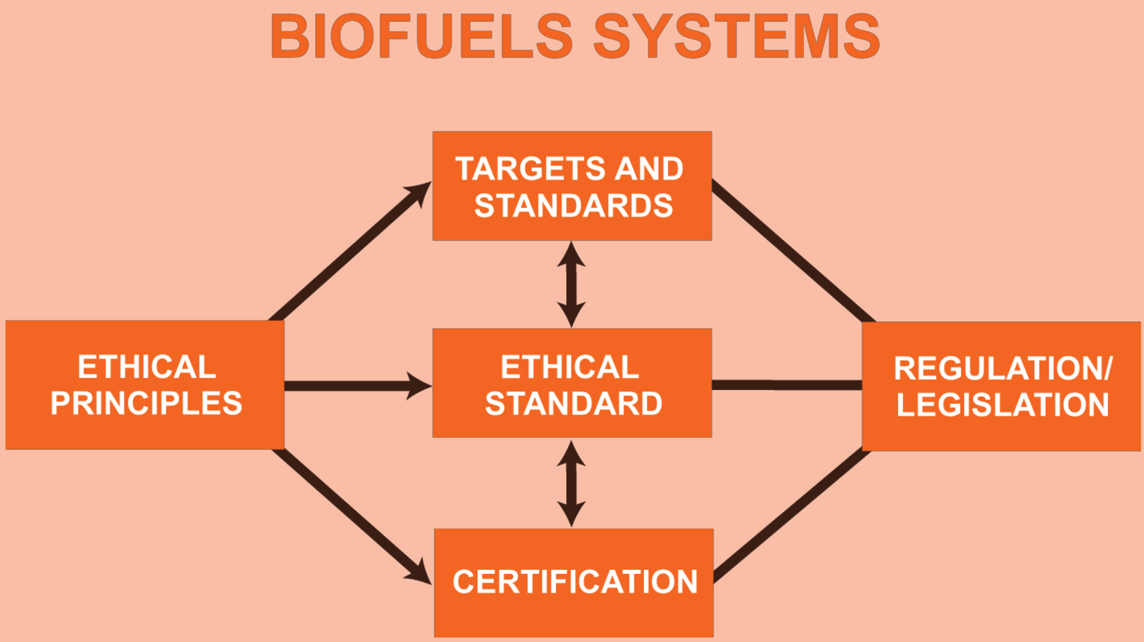
- environmental sustainability for agriculture;
- international agreements on climate change mitigation;
- land use and zoning policy; and
- safeguards to protect human rights, just reward and the equitable distribution of harms and benefits.

6.41 In the previous chapter, we mentioned some instances where such integration would be particularly desirable and made recommendations where we believe that some biofuels-related problems should be dealt with through changes in existing policy. The most important example of this is our suggestion that the best way to deal with the problem of indirect land use change is to tackle land use change as part of a wider framework of global agreement on a coordinated response to climate change.

6.42 However, changing the broader policy landscape to support the ethical development, production, use and trade of all agricultural and related products is beyond the scope of this report. If the difficulties experienced in reaching global agreement on climate change policies are any indication, it will require coordinated and sustained effort to shift the relevant policy fields towards more ethical practices and to ensure their effective implementation and oversight. In the meantime, several ethical issues related to biofuels require immediate attention.

6.43 Box 6.3 outlines elements of a proportionate governance approach, the central features of which, alongside our Ethical Principles, are standards, targets, certification schemes and regulatory systems.

Box 6.3: Proportionate governance approach



6.44 Current biofuels targets, such as the RED target, have contributed to the rapid adoption of sometimes inferior biofuels production and have thus indirectly led to some of the ethical issues discussed in earlier chapters. Targets of the type used in the RED are very blunt instruments, and we believe that the incentivising of a particular technology development should be more sophisticated and responsive.

6.45 Besides the bluntly successful incentivising of production, targets have one major advantage: if stable and consistent, they provide a reliable planning framework for those involved in development and production of biofuels, in particular for farmers and industry. We believe that a long-term view is important in biofuels policy; however, targets also need to be realistic. It is highly likely that most EU Member States will fail to fulfil the current RED target. Targets also have to display a sufficient degree of flexibility to reflect the significant uncertainty in the biofuels area, as well as its heterogeneity and the complex, international interplay between many different stakeholders. Most importantly, within an approach underpinned by strong Ethical Principles, targets should enable appropriate reaction to any of their problematic unintended consequences. We therefore suggest that current RED and national biofuels targets be replaced with an alternative strategy, also target based, that continues to drive forward change, but in a more flexible, nuanced and responsive way.

6.46 **We recommend that policy makers at the European Commission level and in Member States replace current Renewable Energy Directive and national biofuels targets with an alternative, proportionate, target-based strategy that is in accord with our Ethical Principles and that drives change in a more nuanced, flexible and responsive way.**

6.47 Biofuel-specific standards and certification schemes, continually improved, will be important instruments of change in biofuels developments. They will be most effective if they are accompanied by elements from regulatory systems, for example financial sanctions, and incentives such as subsidies or assured markets where specific standards are met. However, so far, despite the best intentions, the outcomes of such initiatives have not been entirely positive. Our policy recommendations refer to the need to use these instruments intelligently to effect improvements in biofuels systems, and this requires continuing monitoring of impacts.

6.48 **We suggest the development and implementation of a comprehensive ethical standard for biofuels, to include the protection of human rights and the environment, full life cycle assessment of greenhouse gas emissions, trade principles that are fair, and access and benefit-sharing schemes. It should be set within wider frameworks for mitigating climate change and addressing land use change (direct and indirect), and should be open to future revision as needed.**

6.49 Standards need to be enforced, and the instrument of choice to ensure this is certification. There is a clear requirement for certification already built in to the RED. For the most part, this now sits with Member States, which have been called upon to develop national certification schemes. Fuel suppliers are making preparations for compliance with the associated national regulations. The differences in requirements among Member States have already resulted in operational and administrative challenges; compliance, for example, is complex when certification requirements vary across the EU. Certification, as it is envisaged here, implements our Ethical Principles, which should ideally apply across all EU Members States, if not globally, with accompanying efforts in monitoring its impacts.

6.50 **The ethical standard for biofuels should be enforced through corresponding certification for all biofuels developed in and imported into the EU. We recommend that, instead of voluntary schemes developed by each Member State, a unified certification scheme be developed and implemented. Such certification should allow for proportionate application, for example in the case of local small-scale biofuels production. The EU should provide financial support and advice to countries who might find it difficult to implement such certification.**

Why just biofuels?

6.51 We have suggested above that a comprehensive standard should be applied to biofuels production through certification. However, several elements of the standard and the associated certification scheme should ideally be applied equitably to all similar products and not just biofuels. There is no reason why our ethical framework and its Principles should apply to just one sector of agricultural and technological activity. In particular, the considerations flowing from Principle 6 apply to many technologies and activities, not just to biofuels. Indeed, there is a risk that in putting barriers (i.e. ethical conditions) in the way of biofuels development, this could inhibit their development, while the Principles we have developed continue to be violated in other agricultural, energy generation or trade practices. We therefore propose that our Ethical Principles be used as a model or benchmark in *all* comparable technologies and products, taking one important step towards the development and improvement of the wider policy context that is needed to tackle the enormous challenges of the future. This implies a very ambitious and challenging prospect for those devising and implementing the necessary policy instruments. However, we should attempt to go as far as possible along the way to meeting relevant standards in the context of global climate change.

6.52 **We recommend that our Ethical Principles be applied, ultimately, as a benchmark to all comparable technologies and products.**

Bringing it all together

6.53 The focus of this report is on biofuels because of ethical concerns that have arisen as a result of the very rapid adoption of early generation biofuels. The biofuels focus, while pragmatic, might be potentially problematic. As described in earlier chapters, biofuels are only a small part of both energy and agricultural policy. However, it is important to emphasise that the principles we have developed are much more widely relevant and can – and should – be applied across the board.

6.54 Despite the fact that biofuels will, in all likelihood, constitute a small contribution towards overall world fuel use, this is nonetheless an important contribution. In the increasingly heterogeneous fuel and energy portfolios of the future, each contribution from a sustainable liquid fuel source will be meaningful.

6.55 With respect to energy policy, as stated in the Introduction, reduction and decarbonisation are key priorities. However, biofuels have a role to play during the transition to other solutions. Furthermore, it is likely that biomass will continue to be important for replacing other fossil fuel derived products, such as plastics, even after the fuels themselves have been superseded. The ethical framework we propose will continue to be useful both in assessing other fossil fuel replacement solutions as they emerge, and in assessing biomass feedstock production for other purposes.

6.56 Similarly, agricultural production of feedstock for biofuels must be considered in the light of wider agricultural and trade policy. There are many competing uses for land including the production of food, clothing (e.g. cotton), building materials (e.g. wood) and fuel, as well as the provision of ecosystem services. There is increasing pressure on all these resources as the world population increases, and, here again, reducing waste and excessive consumption, along with decarbonisation of the supply chains, are priorities. The framework we have developed for biofuels can be used in this wider context to promote optimal land use in any one situation, and equitable distribution of the benefits of such use.

6.57 This chapter has reinforced the point that there is no single solution to the primary question for this report – enabling biofuels to contribute, as appropriate, to mitigating the 'perfect storm' while also complying with our Ethical Principles.

6.58 Major challenges to be addressed in meeting this goal relate to:

- broadly, the need for many changes in the wider policy landscape in order to ensure that ethical standards are upheld in all relevant areas of human intervention; and

- more specifically, the deficiencies in current governance processes relating to production systems for biofuels, now and in the future, leading to the need to strengthen and integrate standards and to improve oversight to enable biofuels production to meet the requirements of our Ethical Principles.

6.59 The degree of international coordination needed to address these deficiencies will be challenging. However, we believe that the ethical framework we have proposed will be helpful to policy makers as a basis for consideration of each biofuels system, from the point of view of its properties as a product, and of the production system from which it is derived, to identify the most urgent deficiencies and the most effective and feasible policy options to implement our Ethical Principles.

Appendices

Appendix 1: Method of working

The Nuffield Council on Bioethics established the Working Party on Biofuels: ethical issues in 2009. Ten meetings were held over a period of 14 months.

As part of its work, the Working Party held evidence-gathering sessions with stakeholders; these meetings took the form of a discussion. Details of attendants are given below.

The Working Party would like to express its gratitude to those who attended these meetings.

Meeting with scientists

2 March 2010, 9:30 am–1 pm

Professor Galip Akay
Professor of Chemical Engineering, Newcastle University

Professor Claire Halpin
Professor of Plant Biology and Biotechnology and Deputy Head of the Division of Plant Sciences, University of Dundee

Dr David Leak
Reader in Applied Microbiology, Imperial College London

Dr Gary Leeke
Lecturer in Chemical Engineering, University of Birmingham

Dr John Love
Senior Lecturer in Plant Molecular Biology, University of Exeter

Professor Simon McQueen-Mason
Researcher in Plant Cell Walls, University of York

Meeting with industry

2 March 2010, 3 pm–6 pm

Dr Ben Graziano
Technology Commercialisation Manager, Carbon Trust (then Advanced Bioenergy Accelerator Programme Coordinator, Carbon Trust)

Dr Edward Green
Chief Executive Officer, Green Biologics

Gabriel de Scheemaker
Chief Executive Officer, Cellana

Richard Stark
Advocacy Manager Renewables, British Sugar (then Head of Commercial Development, British Sugar)

Alexander Vogel
Head of Division for Application Technology and Head of Section for Gas Utilisation, E.ON Ruhrgas AG (then Department Manager Research and Development)

Meeting with civil society groups

24 March 2010, 3 pm–7 pm

Meredith Alexander
Head of Trade and Corporates, ActionAid

Rupert Fausset
Principal Sustainability Advisor, Forum for the Future

Dr Benedict Gove
Senior Conservation Scientist, Royal Society for the Protection of Birds

Dr Valerie Kapos
Senior Programme Officer, United Nations Environment Programme–World Conservation Monitoring Centre

Helena Paul
Co-director of Econexus, representing Econexus and Biofuelwatch

Richard Perkins
Senior Commodities Adviser, WWF-UK (then Senior Policy Adviser on Agricultural Supply Chains, WWF-UK)

Ellen Raphael
Then Director UK, Sense about Science

Kenneth Richter
Biofuels Campaigner, Friends of the Earth England, Wales and Northern Ireland

Helen Wallace
Director, Genewatch

Meeting with regulators and expert commentators

5 June 2010, 3 pm–6 pm

Greg Archer
Managing Director, Low Carbon Vehicle Partnership, and Board Member, Renewable Fuels Agency

Dr Ausilio Bauen
Head of BioEnergy Group, Imperial College London

Aaron Berry
Head of Carbon & Sustainability, Renewable Fuels Agency

Dr Nicki Curtis
Senior Policy Advisor, Intellectual Property Office

Duncan Eggar
Biotechnology and Biological Sciences Research Council Bioenergy Champion

Professor Mark Harvey
Director of Centre for Research in Economic Sociology and Innovation, University of Essex

Davinder Lail
Project Manager, Climate Change Policy Team, Department for Environment, Food and Rural Affairs

Dr Patricia Thornley
Research Fellow, Tyndall Centre, University of Manchester

David Turley
Policy and Strategy Manager, National Non-Food Crops Centre

Dr Jeremy Woods
Lecturer in Bioenergy, Imperial College London

Meeting with representatives of Department for Transport

2 February 2010

Dr Victoria Hodkinson-Gibbs
Deputy Director, Cleaner Vehicles and Fuels Division

Dr Samantha Waugh
Head of Biofuels Policy

Meeting with representatives of Novozymes

25 March 2010

Lars Hansen
Regional President, Novozymes Europe

Kaare Riss Nielsen
Head of Public Affairs

Appendix 2: Wider consultation for the Report

The aim of the consultation was to gain the views of interested professionals, organisations and members of the public. The consultation was available online and publicised in both national and specialist media. It comprised a document containing background information and 24 questions. Respondents were invited to answer as many of these as they wished. Ninety-three responses were received, 50 of which were from individuals, and 43 of which were from organisations. The Working Party would like to thank all those who responded to the consultation.

The responses were distributed to the Working Party and informed their deliberations. This summary of the consultation responses does not attempt to reproduce exhaustively all the comments made by the respondents, nor is it a systematic selection. Instead, the summary aims to identify broad areas of consensus, as well as significant or unique points in the debate. To aid the reader in their navigation of the material, comments have been clustered around themes, for example, food security, environmental sustainability etc. We tried to avoid redundancy wherever possible. However, due to the interconnectedness of many of the issues, there remains a certain degree of thematic overlap. We felt that this was appropriate, as it serves to highlight the complexity of the debate. Indeed, many respondents did not limit their comments to the issue mentioned in a particular question, but rather offered analyses of the interactions between several aspects – for example food security, environmental impacts, and land use – and how these could contribute to benefits, or lead to harms in biofuels development and production.

The opinions and recommendations expressed in this summary are intended to reflect those of the consultation respondents and do not necessarily reflect the views of either the Council or the Working Party. The consultation was open to anyone to respond, rather than being conducted as a survey or poll. As such, the responses cannot be interpreted as an accurate representation of the population. The complete text for all responses for which the Council was given permission to publish may be found at the Council website.[562] A version of the original consultation document can also be found on the website.[563] Technical terms are explained in the Glossary.

1 Food security

Issues relating to food security are important in the context of biofuels. For example, when respondents were asked for their opinion on society using more biofuels, several respondents were in favour as long as food security was not compromised. Conversely, several respondents were against such a move, stating that biofuels production contributed to increased demand for land, raised food prices, speculation on food markets, and thus food insecurity. Many respondents mentioned threats to food security (e.g. posed by increased competition for agricultural resources such as land, fertiliser, water, etc.) as one of the most important ethical challenges raised by new biofuels. Although there was a view that countries like the UK could be affected, threats to food security in the developing world were highlighted in particular. Several respondents also thought that policy should focus on food security in the context of biofuels as a priority.

With regards to some of the new approaches to biofuels such as lignocellulosic biofuels and algal-based biofuels (ABBs), respondents were asked whether they believed these would cause problems in relation to food security. A summary of the responses is given below. Some respondents did not answer. Those who did submit responses were broadly divided, with some suggesting that new biofuels were likely to threaten food security, and some believing that new biofuels could avoid conflicts or reduce these i.e. relative to current biofuels. Several respondents even suggested that new

[562] See: http://www.nuffieldbioethics.org/.
[563] Nuffield Council on Bioethics (2009) *New approaches to biofuels: consultation paper*, available at: http://www.nuffieldbioethics.org/sites/default/files/Biofuels%20Consultation%20Master%20-%20PRINT%20FINAL.pdf.

biofuels or biofuels in general could *aid* food security. Suggestions were made for governance; interestingly, there were those that could apply to production of any biofuel type.

a) New biofuels could reduce or avoid food security harms, or could be beneficial in other ways

Avoids or mitigates harms

- New biofuels production does not make use of the edible parts of food crops, and therefore removes a direct threat to food security.
- Some new biofuels can be derived from feedstocks that can be grown on land unsuitable for crop production (e.g. nutrient-efficient perennial trees and grasses, feedstocks designed to grow under stress conditions). This removes direct competition for arable land.
- Some new biofuels can be produced from feedstocks that do not require any land (e.g. wastes, marine algae).
- New biofuels produced via the lignocellulosic pathway provide more energy per plant, per hectare of land and per inputs compared to current biofuels, therefore minimising agricultural requirements and reducing any conflict with crop production.
- Cultivation of some algae could require land but the demand is likely to be less compared with current biofuels given the potentially high biomass productivity of algae.
- With regards to the effects of new biofuels in developing countries on food security, these will be minimal given that developing countries will be unable to invest in new biofuels on account of the prohibitive costs.

Potential benefits

- Cultivation of some lignocellulosic crops (e.g. perennial grasses) can reduce the need for fresh water and improve the land's soil quality, stability, and carbon stocks for any future production of food crops.
- Production of grain crops will be incentivised to meet the market demand for agricultural residues that are to be used in lignocellulosic biofuels production.
- Technology transfer of new biofuels to developing countries could benefit research and development (R&D) in food production there. There is significant opportunity for improvements as currently food production is below its full potential in many developing countries.
- In general, biofuels could create income-generating opportunities for farmers in developing countries; with this income, individuals could buy food. This has been seen with Brazilian sugar cane bioethanol.
- Use of biofuels generally can mitigate climate change and its adverse effect on food crop production around the world.

b) New biofuels could harm food security

- New biofuels, despite avoiding the edible parts of food crops, will threaten food security due to increased competition for agricultural resources, e.g. land, water, human capital etc.

- Using agricultural residues will impact on feed availability for livestock, limiting livestock numbers for food production. In addition, more land could be cultivated to make up the shortfall in feed, taking the land out of crop production for humans.

- Use of wastes from agriculture and forestry will prevent these from being recycled into the soil. As such, the soil will be depleted of nutrients, affecting any future arable farming there.

- Although some new biofuels feedstocks can be grown under sub-optimal conditions (e.g. low inputs, low quality soil), there will nevertheless be an economic incentive to cultivate these under optimum conditions and on a large scale in order to achieve greater returns.

- The focusing of R&D and human resources on the production of new biofuels could limit the development of food crops, e.g. such that they too are able to grow in hostile conditions.

- Some new biofuels feedstocks can be cultivated on less fertile land (e.g. nutrient-efficient perennial crops); however if the land is fertile enough to grow biofuels crops, it is also fertile enough to grow food crops, e.g. using genetic technologies or advanced farming practices.

- There will be an economic incentive to cultivate algae on flat land, and ABBs could also draw significantly on freshwater supplies. Algae grown offshore might conflict with fisheries.

- The exercise of intellectual property rights (IPRs) over new biofuels feedstocks could effectively remove some crops from food and feed in developing countries.

- If current incentives change such that biomass feedstocks are competitive with grain prices, higher quality arable land will be converted to biofuels crops. This has been the case with cash crops such as tobacco and cotton.

c) Observations for developing countries regarding food security

- In developing countries, even small impacts on food security can be a matter of life and death and lead to social conflict:

  a Food insecurity is often already endemic and severe here, e.g. due to poor growing conditions and farming practices, and adverse climate change effects.

  b There are fewer regulatory ‘safety nets’ both to prevent harm (e.g. agricultural subsidies) and to protect citizens against it (e.g. state provision of benefits).

  c The poorest people already devote a large proportion of their income to food so that any price increase has a larger effect proportionally.

  d Subsistence farming is common, which increases the directness of the risk.

- There is not a neat ‘developing/developed world’ divide. Whether there are harms will be determined by the availability of land and other resources, and political and social infrastructures (e.g. sustainable farming practices). The public opinion of genetic modification could also be a determinant.

- Food security in developing countries is affected by more than biofuels alone. Poor growing conditions and farming practices are also contributors. Thus, food security should not be used as a barrier to the adoption of biofuels.

- In developing countries, current biofuels production is linked with hunger not because the land used could be used to produce food crops, but because their production denies individuals the land or labour wage to feed themselves.

- There is a risk of 'green imperialism', a situation where, directed by land and resource availability, developed countries produce new biofuels in developing countries for their markets back home.

d) Suggestions for governance on food security

- Global food security and food sovereignty should take primacy over biofuels production.

- There is potential for new biofuels production to have minimal impact on food security; however, this can only be realised through appropriate governance.

- There is a need for joined-up thinking. For example, whilst some suggest the prohibition of biofuels crops on arable land, this potentially encourages the clearing of natural land.

- It is necessary to ensure that biofuels development does not interfere with any measures intended to aid food security in the context of climate change, such as dedicated programmes of crop production or R&D into stress-tolerant crops.

Specific potential measures regarding food security

- Certification schemes could be used. For example, the developed world could only source biofuels that have been certified as not harming food security.

- Regulation of land use could licence cultivation of biofuels feedstocks when arable land is in surplus. In developing countries, purchase of land by foreign companies could be prohibited if it is likely to be at the expense of domestic food production.

- Large-scale production could be avoided. Furthermore, a range of feedstocks could be used, with each requiring a different set of agricultural inputs. This could help diversify pressures on food security.

- It could be ensured that developing world farmers are not incentivised to produce cash crops at the expense of food.

- An access and benefit-sharing mechanism could be devised for biofuels production which considers food and feed crops of importance to food security. This could help to avoid negative impacts on food security from IPRs.

2 Land

Land issues are clearly important to the biofuels debate. A few respondents mentioned that it was acceptable for society to move to an increased use of biofuels as long as, for example it did not compete for land that would otherwise be used for food crop production or remain under natural forest. Many respondents considered land issues to be some of the most important ethical challenges raised by new biofuels. Examples included: the allocation of land given its limited availability and the plurality of demands; and land use that was socially and environmentally sustainable. Several also mentioned land issues as policy concerns to be prioritised, including those relating to land ownership in developing countries.

Respondents were asked whether they believed new biofuels would cause any problems with regards to land. Some respondents did not answer; another respondent mentioned they felt not expert enough to do so. It was apparent that many believed that new biofuels *would* create problems, for example by increasing land demand; however, several respondents believed that they would be better than current biofuels due to their reduced demand for land. A few suggested there would be no issues. Where respondents believed that new biofuels were likely to cause problems, there was in a few respondents the recognition that this issue affected agriculture as a whole and was not specific to biofuels.

The environmental and social consequences of land use are not presented below as these are clustered under the other themes, e.g. food security, environmental sustainability etc. Below is an outline of the debate regarding the demand of new biofuels for land.

a) New biofuels might avoid or mitigate land demand

- Use of wastes, e.g. from agriculture, forestry and municipal waste streams, and offshore algae will not require any land use per se.
- New approaches making use of wastes could reduce the space required for landfills.
- There will be reduced demand for agricultural land given that some new biofuels feedstocks can be grown on poor quality agricultural land or marginal land. Cultivation of some algae will also not require fertile land.
- Use of the entire crop in lignocellulosic biofuels production will enable greater energy yields per crop, per area of land, enabling land demand to be minimised.
- In addition, some new biofuels feedstocks are high yielding, or yields might be increased using genetic technologies – again, reducing land demand.
- Some new biofuels feedstocks help to improve soil quality by fixing carbon in the soil. Arid land could also be revitalised in developing countries.

b) New biofuels could increase land demand

- There will be increased land demand unless production uses feedstocks exclusively derived from existing waste streams.
- Large-scale cultivation (domestically or abroad) will be necessary: to produce sufficient amounts of biomass to replace current fossil fuel use; to achieve economic return on high initial capital costs; and to meet targets.
- Despite feedstocks that can be grown on land of low agricultural value, there could be an environmental incentive to use cropland since this has a low carbon stock.
- There will be an economic incentive to grow even low-input new biofuels feedstocks on fertile land to achieve greater yields and economic returns.
- There are existing considerable demands for land, such as rising world population, growing demand for meat etc. This raises the question whether new biofuels should be cultivated.
- In developing countries, 'underutilised' land already has other purposes, e.g. grazing, foraging, and firewood harvesting. It might also be used by nomadic herders at various points in the year. The use of such land will generate increased demand for land to replace these purposes.
- The exertion of IPRs could prevent developing countries from adopting feedstocks that are more sustainable with regards to land use.

c) Observations for developing countries with regards to land

- There is likely to be greater land use in some developing countries because of their favourable climate and the amount of available land. Furthermore, some of the richest habitats exist here and food security is already an acute issue. Thus, the threats of land use are much greater here.

- Land ownership in developing countries is often poorly defined or informal, making communities there particularly vulnerable to displacement. For example, communities – and in particular women – might have only customary use of land with no security of land tenure.

- Communities are often unlikely to be consulted where governments agree to lease land to foreign companies. Also, in negotiations over land ownership, they typically have little leverage against large private corporations.

- Communities giving up their access or rights to land could effectively deprive themselves of local resources on which they depend, e.g. for food, feed and fuel.

- Developing countries can have less stringent environmental and social safeguards in place for agricultural land development. In addition, there is a risk that practices considered inappropriate in developed countries will be operated here by foreign companies due to weak governance.

- There are different priorities in developing countries for land, e.g. economic development, gender issues, energy access. These can take priority over food security and climate change mitigation.

- A trend is developing where developed countries use land and associated resources in developing countries for their own purposes. These actions, sometimes known as 'land grabs' (a term reflecting the controversial nature in which the land can be obtained) can be great in scale and can involve violence. Such a trend could be observed with biofuels production.

d) Other observations with regards to land

- Land demand depends on the feedstock used, the existing farming practices and the scale of development. For example, the land demand for algal-based biofuels will depend on whether algae are cultivated offshore or in photobioreactors.

- There are only a few examples of land use change causing problems, including threats to food security and environmental harms; it is wrong to focus solely on these exceptions.

- Currently there is no good, agreed-upon methodology for assessing land use. There are doubts as to whether indirect land use change (iLUC) can be monitored accurately.

- Underused agricultural land offers significant potential, particularly in view of feasible biomass yield increases.

e) Suggestions for land governance

- Land issues should be discussed at an international level given the global dimension of land use. There is a need, however, to make evaluations on a case-by-case basis so that local complexities and views are understood.

- A political framework to ensure sustainable land use is required. For example, there could be legislation, land-use planning or certification at the international, country or regional level.

- There is a need for interdisciplinary discussions, e.g. there should be consideration of the development agenda.

- Any land regulation should be transparent and based on evidence.
- Land use change and its consequences are neither new nor restricted to biofuels. Thus, in the interests of fairness and to prevent 'leakage' of bad practices into other areas, the scrutiny applied to biofuels should also be directed towards other uses of land, e.g. other agriculture or urban development.

Specific potential measures regarding land use

- There could be a role for public scrutiny and corporate social responsibility in addressing land use issues.
- Any individual that is adversely affected by land use change (e.g. is displaced) could be compensated by having a stake in the development of new biofuels.
- Degraded land that cannot be used for food production and other ecosystem services could be used for biofuels production. Measures to maximise energy produced per hectare – thus reducing land competition – could also be employed.
- Diversification of feedstocks enables materials to be used from a wider range of land resources. This would aid land security. Furthermore, there is the opportunity to create resource bases that are more sustainable in terms of land for that location.

3 Health and water

Several respondents discussed health and water security in their submissions. The scope of their comments is presented below.

Health issues arising from agricultural pollution were seen as one of the most important ethical challenges raised by new biofuels. It was argued that biofuels production should aim to address health issues due to air pollution. There was a view that challenges to working conditions, for example because of chemical use, were not unique to biofuels production, rather they were common to agriculture in general.

A societal move to increased use of biofuels was disapproved of based on the belief that biofuels had led to water insecurity. In light of growing water insecurity (i.e. because of limited sources and a growing population), the amount of water used in biofuels production (the 'water footprint') was highlighted as one of the most important ethical challenges of new biofuels. Efficient water use was highlighted as a policy concern to be prioritised, and it was elsewhere proposed that new biofuels should aim for lower water consumption. The threat to water security was more pronounced in developing countries where climates were more arid and infrastructure for accessing any water resources was limited.

4 Environmental sustainability

Consultation respondents discussed issues related to environmental sustainability. Several respondents believed that a societal move towards greater use of biofuels was acceptable or favourable if their production was environmentally sustainable, e.g. did not involve ecosystem losses, or provided net greenhouse gas (GHG) emission savings. However, several respondents asserted that increased biofuels use was unacceptable or not desirable as biofuels production led or could lead to environmental harms. They cited land use change which reduced biodiversity and generated GHGs. Many respondents suggested that environmental sustainability was one of, if not the, most important ethical challenge posed by new biofuels. Either environmental sustainability was mentioned specifically or constituent aspects were highlighted, e.g. sustainable use of biomass, land, or water, or conservation of biodiversity. Similarly, some respondents drew attention to environmental sustainability, or its constituent elements, as a policy concern to be prioritised.

When asked about the potential advantages and disadvantages of new biofuels for environmental security,[564] many respondents did not answer. One other respondent wrote that they did not feel expert enough to comment. The degree of certainty with which arguments were made about harms and benefits varied from the absolute to the potential. With regards to dealing with harms, respondents suggested measures that were permissive of new biofuels developments or asserted the need for preventative measures.

a) Environmental benefits of biofuels in general

- Biofuels development removes the need to search for oil in inaccessible or pristine areas, or to make use of tar sands – activities that can pose significant risks to the surrounding environment.
- Biofuels by nature do not pose the same hazards as fossil fuels: e.g. in direct contrast to oil spills, a biofuel spill is not toxic. Biofuels also reduce the amount of fossil fuel used in transport.
- The scrutiny applied to the development of the biofuels industry could improve environmental stewardship in agriculture in general.

b) New biofuels could provide environmental benefits

- Some new biofuels production uses wastes from agriculture and forestry, as well as municipal wastes. This requires neither inputs, e.g. in terms of water and fertiliser,[565] nor land use.[566]
- Use of wastes affords a means of dealing with waste which can otherwise decompose, causing environmental harms, e.g. GHG production.
- With lignocellulosic biofuels production, the whole feedstock is used, which maximises the energy-input ratio, and thus minimises the amount of water, fertiliser and land used with regards to biofuels yield. In addition, some feedstocks, such as energy grasses, require less fertiliser, herbicides and pesticides than arable crops. This minimises any subsequent air or water pollution.
- Some new biofuels feedstocks (e.g. algae, certain energy grasses) can be grown on less hospitable land, such as that with low soil quality, aridity, lack of freshwater etc. This reduces the drive for land use change of natural land. Where new biofuels feedstocks are grown in less hospitable environments, these environments can be effectively revitalised.
- Some new biofuels feedstocks, e.g. short rotation coppice (SRC) willow or miscanthus, can display greater biodiversity than existing arable crops. Perennial energy crops can also provide flood control.
- New biofuels production using algae can be integrated with biological 'cleaning' of waste water (bioremediation) and with 'scrubbing' of carbon dioxide from factory emissions.
- Development of new biofuels will increase the demand for residues, and could consequently promote agriculture and forestry, affording new habitats and carbon 'sinks'.

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[564] The term 'environmental security' was considered by the Working party to be interchangeable with 'environmental sustainability'.
[565] Fertiliser use can lead to water pollution and GHG emissions.
[566] Any lowering of land use minimises the need for land use change which is associated with GHG production and habitat loss.

c) New biofuels could cause environmental harms

- The use of the whole feedstock and wastes in lignocellulosic biofuel production prevents them being recycled into the soil, and leads to depletion of soil minerals and soil biodiversity.
- It is unclear whether there are large enough areas of land that are suitable for cultivating new biofuels feedstocks (e.g. algae, dedicated energy crops) without causing land use change (either direct or indirect). Additionally, there is doubt as to whether new biofuels feedstocks will require so little inputs of water and fertiliser etc.
- If new biofuels feedstocks are cultivated on land which has reduced agricultural value, this might threaten the biodiversity and ecosystem services already present there.
- The invasiveness of some new biofuels feedstocks, such as switchgrass and miscanthus, threatens local biodiversity. Also, any genetic modification in these crops would therefore be more of a concern. Foreign feedstocks can also harm water balance.
- The disposal of the used medium that algae have been cultivated in is problematic. Also, if seawater is used in cultivation, the land could be made unsuitable for future crop production and extensive infrastructure would also be needed.
- To achieve large-scale production of new biofuels, high inputs of water will be necessary, as well as fertiliser, chemical and pesticide use which are associated with water and air pollution. Monoculture, which threatens biodiversity, is also a likely practice and there will be pressure for land use change.
- Some genetically modified crops that are herbicide tolerant and pest resistant are associated with herbicide-resistant weeds, pest-resistant populations of insect and the emergence of secondary pests that require additional insecticide. Such issues could afflict new biofuels feedstocks that are genetically modified.
- The use of genetically modified trees for lignocellulosic biofuels poses a heightened risk of genetic pollution because tree pollen can travel greater distances. There could be serious environmental consequences if genetically modified microorganisms capable of enhanced cellulase production are released into the environment.
- There is also the issue of large-scale cultivation of genetically modified algae, which could represent a case of wide environmental release if cultivated in open ponds.

Issues of environmental policy

- Unconditional biofuels support in the form of targets and subsidies has been effective in promoting biofuels development but not in ensuring its sustainability.
- The effectiveness of voluntary schemes to certify environmental sustainability is questionable. In the absence of binding criteria, it is unlikely that suppliers will make the efforts to improve their performance.

d) Other comments on environmental sustainability

- More information is needed regarding the issues affecting environmental sustainability, especially with regards to what constitutes a full life cycle assessment (LCA).
- The developing world is likely to be the location for much new biofuels production. The developing world is also home to some of the richest habitats, and any potential environmental harm would be most keenly felt here.

e) Suggestions for environmental governance

- There should be case-by-case evaluation of the environmental impacts of biofuels. Solutions should be local but framed within the global context. International regulation could assist.
- Unified legislation on environmental issues across the board is necessary, which takes into account other targets and agendas.
- It is not appropriate to examine environmental sustainability in isolation of socio-economic issues.
- The current use of fossil fuels is not morally neutral. This needs to be considered when evaluating alternatives like biofuels.
- The precautionary principle should apply: i.e. all of the risks associated with new biofuels must be thoroughly investigated before there is adoption.
- Sustainability criteria need to apply to all uses of biomass to prevent 'system leakage'[567] and must not – without great benefit to the environment – penalise producers.
- Where renewable targets are established with implications for biofuels, they should be complemented by robust, objective and verifiable sustainability criteria.

Specific potential measures regarding environmental policy

- International certification/ traceability schemes could be adopted that verify the sustainability of biofuels based on environmental (and social) criteria.
- Imposition of taxes on unsustainable biofuels practices could curb their development. Tax incentives and input subsidies could promote environmentally sustainable biofuels processes specifically. This would incentivise environmentally sustainable biofuels and also potentially compensate for efforts to comply with voluntary certification schemes. However, these initiatives might come into conflict with World Trade Organization rules.
- GHG emissions, deforestation and other environmental harms, e.g. associated with fossil fuels or current biofuels use, could be accounted for in the market.
- A more technology-neutral and goal-specific approach could be adopted in which governmental support is given to biofuels pathways based on the evaluation of their full life cycle and related externalities.
- Scaling of support based for example, on how carbon-efficient a pathway is, could be adopted.

5 Climate change

Climate change, or issues relating to this, featured often in consultation responses. For example, a few mentioned that increased biofuels use by society was acceptable as long as it did not exacerbate climate change or provided net GHG reductions. Several respondents regarded GHG emissions or climate impacts resulting from land use change as one of the most important ethical challenges raised by new biofuels. Several respondents thought that climate change and related aspects, such as land

[567] I.e. where use of biomass elsewhere, such as in bioenergy production or timber harvesting, continues in a non-sustainable fashion.

use change leading to GHG production, GHG savings, reliable LCA, or the use of other options to mitigate climate change, should be prioritised within policy.

In respondents' submissions on how they felt about society moving towards a greater use of biofuels, there was some discussion on the role of biofuels in climate change mitigation. Respondents were divided as to whether they believed biofuel use would mitigate climate change and as such was desirable/necessary; or that biofuel use would exacerbate climate change and as such was undesirable/should not take place. There was also discussion on the limit of biofuels' role.

When asked which new biofuels would be most successful in generating GHG emission savings, there was little consensus. When asked about how such new biofuels should be encouraged, respondents were divided broadly between market-based mechanisms and those based on certification. A distinction was also apparent between measures that would be technology-specific or goal-specific. Some warned that new biofuels should not be encouraged, or there should be care, based on certain risks they posed. A few respondents presented criteria for considering when new biofuels should not be encouraged. Some respondents did not respond to these questions at all.

a) Role of biofuels in climate change mitigation

- Sustainably produced biofuels contribute to climate change mitigation through reducing GHG emissions produced by transport. As such, they are desirable.

- Biofuels use is an essential part of responses to mitigate climate change given that there are no other carbon-neutral options for fuelling aviation and heavy vehicle transport.

- To have reason to move towards increased use, biofuels must generate net GHG emission savings, which are greater than those that would be achieved if money was invested in alternative renewable technologies.

- Increased biofuels use is only part of the solution for climate change mitigation. Other measures, which are perhaps more cost-effective or efficient, should not be impeded by biofuels. These could include:

  a hybrid vehicles,[568] electric vehicles and vehicles making use of hydrogen fuel;

  b intelligent public transport;

  c use of alternative energy sources – such as solar/wind – in other areas of society;

  d broader societal energy efficiency measures;

  e behavioural changes to lower energy consumption of society;

  f ecological restoration;

  g alternative uses of biofuels, e.g. to power fuel cells that are more energy efficient than the internal combustion engine; and

  h alternative uses of biomass, e.g. for heat, or heat and electricity generation.

- Biofuels use can help mitigate climate change, but this will be necessarily limited in scale to avoid harmful environmental impacts.

[568] Vehicles making use of petrol/biofuel blends and electricity.

- Biofuels produced on an industrial scale exacerbate climate change through increasing net GHG emissions, e.g. by land use change and fertiliser use.
- Increased biofuels use limits or discourages the adoption of other existing potentials to mitigate climate change.
- Biofuels use perpetuates the use of fossil fuels in transport, which contribute to climate change.

b) Most successful new biofuels for GHG emissions savings

- Lignocellulosic biofuels, including biochemical and thermochemical conversion pathways, can be relatively successful with regards to climate change mitigation, since all of the biomass is used. This optimises the energy-input ratio, minimising the need for inputs (e.g. fertiliser, land[569]) and displacing more fossil fuel.
- The use of wastes, e.g. agricultural, forestry, municipal, can reduce GHG emissions as it does not involve the cultivation of any crops and therefore any associated inputs. The use of wastes also avoids the production of GHGs produced by decomposition.
- The use of perennial crops as dedicated biofuels feedstocks – e.g. SRC willow and miscanthus grasses – produces less GHG emissions on account of their low fertiliser requirements.
- ABBs can be successful in producing lower GHG emissions due to the potentially high productivity of algae, the requirement for less land, and the use of waste carbon dioxide gas from power plants.
- The use of genetic technologies, e.g. plant breeding or genetic engineering, can help to achieve GHG emissions savings, e.g. through reducing the need for fertiliser, or raising productivity.
- There is a role for higher energy fuels such as butanol, which optimise the energy-input ratio.

c) Encouraging new biofuels that save GHG emissions

Technology-specific mechanisms

Market-based suggestions

- Financial support, e.g. subsidies, tax concessions etc., could be used to incentivise technologies known to deliver GHG savings, or cultivation of feedstocks that require minimum land.

Goal-specific mechanisms

Certification schemes

- Certification schemes that certify biofuels on the basis of their life cycle GHG emissions should be implemented. Standards could apply throughout the production pathway, e.g. excluding land that has high carbon stocks.
- Certification schemes should be evidence-based, standardised and achieve wide consensus. Certification should occur on a case-by-case basis.

[569] As previously mentioned, any lowering of land use minimises the need for land-use change which is associated with GHG production.

- Certification schemes should be applicable internationally and to other sectors to prevent 'system leakage', i.e. where biofuels production or the agricultural sector elsewhere continues in a non-sustainable fashion.

- Certification schemes should be complemented by robust regulatory mechanisms to ensure compliance. These could include mandatory reporting or the threat of penalties.

Market-based suggestions

- Provision of any support should consider whether alternative low carbon solutions exist.

- Commitment of governments or companies to source certified biofuels would reward and thus encourage their production.

- Taxes on GHG emissions, carbon credits or taxes on fossil fuel use could be used to support the production of any biofuels leading to lower GHG emissions.

More general methods to support biofuels that save GHG emissions

- Greater public investment in R&D and more private investment in mature technologies should take place. There should be sufficient flexibility with regards to investment to avoid impeding development.

- A strong biofuels market supported by long-term, clear governmental policy will encourage further investment – particularly private investment – in biofuels in general.

- Caps on biofuels use could be implemented where demand exceeds what can be supplied, thus preventing expansion into land that is carbon rich.

Other comments on GHG emissions

- Any taxation on liquid transport fuel could be problematic if there are no real alternatives for the consumer.

- It is important that biofuels delivering GHG savings are cost-effective and available in a reasonable timeframe.

d) Reasons for not encouraging GHG-saving new biofuels

Criteria

- New biofuels should not be encouraged if they displace other crops and thus cause iLUC.

- New biofuels should be discouraged if their use harms aspects of human security (e.g. food security, human rights, public health etc.).

- The amount of feedstock likely to be produced for new biofuels will only achieve small GHG emissions savings. Any decision to encourage/discourage must therefore consider the role for other measures too.

- There should be no encouragement if human and economic capital can be better invested in other climate change mitigation strategies.

Risks

- Dedicated biofuels feedstocks will exert demand for land, and could in this way prompt land use change and production of GHG emissions. Large-scale production is likely to be necessary to enable returns on economic investment; this could drive further land use change.

- Use of forestry waste for new biofuels could create perverse incentives leading to deforestation and GHG emissions production. This is especially relevant to some developing countries where governance is weak. The use of forestry wastes – typically used as organic fertiliser – could also lead to nutrient depletion of soil, soil erosion and losses of soil biodiversity.

- In developing countries, agricultural and forestry wastes are already used, e.g. for heat and power generation; sources of cooking fuel, fertiliser or animal feed etc. Use of these residues for new biofuels could drive greater use of fossil fuels in substitution. iLUC could also be caused if the residues are replaced by growing crops on land elsewhere.

- There are alternative uses of biomass that are better in terms of the energy yield and the net GHG emissions savings. Examples are biomass combustion for heat or heat and power, or co-firing power stations. Use of biomass for new biofuels could limit these methods.

Other comments on new biofuels and GHG emissions

- Not enough data exists to predict which of the new biofuels will be most successful in achieving net GHG reductions. It is unlikely that there will be a single new approach that is adopted. Different locations are likely to require different and perhaps multiple solutions.

- All new approaches should be considered. It is risky to consider endorsing a single technology given present uncertainty and the need for suitable approaches for different locations.

- New biofuels could provide GHG emissions savings but are currently not a realistic prospect. More R&D is needed to realise their potential.

- Current biofuels production should not be disregarded; there are ways of improving their GHG savings. Additionally, they are important for paving the way for new biofuels, e.g. driving sale of flex-fuel vehicles, encouraging the implementation of biofuels infrastructure etc.

6 Just reward and fairness of trade

In their submissions, respondents described issues that related to just reward and/or fairness of trade. For example, when questioned about the most important ethical challenges raised by new biofuels, fair return for farmers and appropriate wages and working conditions for workers were mentioned. Transparency of revenue dispersal was cited as a policy concern to be prioritised. Many responses regarding intellectual property (IP), land use and the rights of farmers and workers clustered around issues of just reward and fair trade. These typically related to developing countries. In these responses, there was mainly the view that new biofuels would cause problems related to just reward and/or fair trade. However, there was also the view that this depended on other factors and the problems were not exclusive to (new) biofuels production. Respondents also made suggestions for policy.

a) New biofuels could cause problems related to just reward and/or fairness of trade

Issues for farmers, workers and communities

- Market pressure for cheap biofuel will drive biofuels production in countries with minimal employment welfare standards (e.g. regarding wage and working conditions) so that companies are able to increase their profit margins.

- Large-scale production will dominate new biofuels production, enabling producers to benefit from economies of scale in achieving returns on sizeable investments. Historically, transitions to large-scale corporate production have been associated with deteriorating employment standards.. Large-scale monoculture often leaves little profit at the local level.

- Large-scale production will increase the demand for land; this may pressurise local communities to give up their right of access to land that has economic, cultural or social value. Even so-called 'unused' land often has uses, e.g. grazing, firewood harvesting.
- Communities who have given up their right to land could be deprived of their rightful share of benefits derived from any future biofuels production on this land.
- There is a question as to whether it is ethical to enforce upon rural populations in developing countries a particular means of earning a living. This has happened for example with jatropha cultivation in some Asian countries.

Intellectual property issues

- There is a risk that traditional knowledge could be appropriated by companies, denying the community that developed the knowledge both the benefits of its day-to-day use and just reward from its use in new biofuels production.
- The same concerns may arise over naturally-occurring varieties that are indigenous to a particular location/country and appropriated for new biofuels production.
- The extensive use of genetically modified crops for new biofuels could mean that farmers using them become 'hostage' to expensive licensing agreements with the major seed companies. For example, the use of patented seeds can prevent the farmer from saving part of their crop for seeding next year. Thus, farmers may suffer financially due to seed producers demanding high prices and biomass traders offering low prices for biomass.
- New biofuels development is likely to require high levels of investments and developers will seek to protect this. They will try to achieve financial reward through exercising any IPRs.

b) New biofuels might not cause problems related to just reward or fairness of trade

- Technologies that reduce the need for new land – for example, lignocellulosic biofuels derived from waste – will reduce the risk of violating communities' right to access land.
- In developing countries, the trend towards industrialisation of agriculture in both food and fuel production could lead to improved labour standards and improved employment regulation.

c) Observations for the developing world regarding just reward

- Governments leasing land to foreign companies for the cultivation of feedstock are unlikely to engage local communities to identify their needs and perspective.
- There are fewer – or less well-enforced – regulatory safeguards for employment, e.g. regarding wages, health and safety.
- There is a risk of unscrupulous developers employing child labour.

d) Other observations regarding just reward

- Whether new biofuels will raise problems related to the rights of farmers and workers depends on which new biofuels approach is adopted, the scale and ownership of the production facilities, and how the new industry develops with regards to wider society.
- The negative effects on workers' rights seem to have less to do with the form of production and more to do with the existence of adequate frameworks at the national level for the protection and enforcement of labour rights.
- Land use issues are not exclusive to new biofuels production; they will arise where any agricultural or industrial practice requires land. Similarly, concerns regarding inadequate wages for workers/farmers and poor working conditions are common to the employment in the agricultural sector in general.
- There is little room for investors to profit from high-tech innovations in the new biofuels production chain which have been protected by IP, as ultimately the end market is a commodity market.

e) Suggestions for just reward and fair trade governance

Protecting farmers and workers

- There is a need to establish governance that is fair to all stakeholders, i.e. investors, companies, groups possessing traditional knowledge and making use of local varieties, farmers and workers.
- Projects developed together with local communities will favour the implementation of farmers and workers rights. The formation of strong cooperatives could also play a positive role.
- There could be recognition of farmers and workers as co-owners/participants of new biofuels production, rather than just feedstock producers. Indeed, recognition of local contexts by biofuels companies using local farmers and contracted workers has had little direct negative impacts on land access, and has represented a more positive model for local livelihoods.
- Corporate social responsibility and reputation management could be effective in preventing poor practices by companies, and there is a role for sharing best practice as the industry evolves. The Brazilian Government publishes a list of companies engaged in the sugar cane industry that have been found to use slave labour. By citation on this list, a company loses access to some federal finance.
- The implementation of national and/or international legislation regarding the rights of farmers and workers, such as the International Labour Organization Conventions, could be sufficient.

Protecting communities

- When companies acquire land, the free, prior and informed consent of the communities involved should be secured with adequate consultation. Compensation should be provided where appropriate. Moreover, developed countries should give compensation to any developing country losing economic development opportunities by keeping some land unconverted to achieve environmental sustainability.
- Policies which encourage land tenure development should be promoted in developing countries so that farmer groups have a recognised right to access land.
- It is important that biofuels production commits to transparency. It should be possible at any moment for companies to report about their business model and impacts on people and the environment. A standard/certification might achieve this objective.

Intellectual property issues

- The country of origin could have a share of the IPRs associated with new varieties.
- IP rules should prevail as according to international law. With regards to subsistence farming, the Convention of the International Union for the Protection of New Varieties of Plants (UPOV) contains a compulsory exception to the breeder's right whereby the breeder's right does not extend to acts done privately and for non-commercial purposes (breeder's exemption). Parties to the UPOV Convention may also permit farmers on their own farms to use part of their harvest of a protected variety for planting crops in the future.
- Commercial interests might require protection of just reward in new ways, e.g. through prize funds, patent-pooling, or open-source models.

7 Equitable distribution of costs and benefits

In their submissions, respondents described issues that related to the equitable distribution of costs and benefits. For example, some respondents described issues of this nature when discussing the most important ethical challenges raised by new biofuels, and several respondents described these as policy concerns which should be prioritised. These included, for example: the access of rural communities in developing countries to new biofuels production; technology-transfer; and the use of resources in developing countries for the production of biofuels destined for use in developed countries – and potentially at the expense of developing countries' food production and environment.

Of those who responded to the questions regarding IP/ access issues, and potential problems for farmers and workers,[570] some discussed issues relating to the equitable distribution of costs and benefits (these typically related to developing countries, though IP issues related to both the developing and developed world). There was a view that new biofuels could cause such problems. A few cited the importance of other factors – such as governance or the type of biofuel adopted – in determining whether any problems emerged. A few respondents also commented that the IP/access issues were not new or specific to new biofuels. Respondents also made suggestions for policy, the majority of which related to the developing world context.

a) New biofuels could raise problems that relate to equitable cost–benefit distribution

Regarding farmers and workers

- Developing countries may lack financial capacity or skilled personnel to engage with new biofuels, given that new biofuels are likely to be more technology intensive than current biofuels.
- Large-scale production will dominate new biofuels production to enable producers to benefit from economies of scale. Research into the highly-capitalised, industrialised sugar cane industry has shown that there is a low demand for labour from poorer groups, e.g. due to mechanisation, and that the model is incompatible with traditional farming methods. This has contributed to an increase in economic inequality and a lack of autonomy on the part of the rural poor.
- New kinds of job will require different skills; it may be easier to bring in a new workforce rather than re-train the existing workforce.

[570] Many respondents did not respond to the question on intellectual property and access issues. Some respondents did not respond to the question regarding the rights of farmers and workers.

- The model of biofuels production for an export market that simultaneously benefits domestic economic development could be simplistic. Historically, such production has largely benefitted those controlling the plantations, as well as fuel companies and international commodity traders. Local communities have suffered because of for example, slave-like working conditions, forcible removal from their land etc.

Intellectual property and access issues

- The existence of IPRs – and restrictive exercise of these – could raise issues of access by other new biofuels developers, e.g. to enzyme technologies, conversion processes, and plant varieties.

- The IP/access issues are not in principle different from those seen in other areas of biotechnology. However, some of the problems may be more pronounced given the fragmentation of research efforts, with different groups sponsored by different industrial partners, thus making communication more difficult.

- IPRs could generate issues of access in particular by groups in developing countries, which cannot afford the costs of licensing. This would impede technology transfer and raises the spectre of a possible 'biofuels technology divide'.

- Given the range of technologies likely to be involved in the production of new biofuels, the area seems particularly prone to patent-stacking and patent-thickets.

- Developing countries which own IPRs for organisms could be overprotective, and thus hinder research progress.

b) New biofuels might not raise problems that relate to equitable cost–benefit distribution

Regarding farmers and workers

- Production of new biofuels could create more jobs especially in rural areas.

Intellectual property and access issues

- IPRs could facilitate technology transfer. Published patent documents constitute an accessible global source of information, translated into various languages. Technological development is then dependent on a country's ability to use the technology.

- Compared to their role in the pharmaceutical industry, IPRs will play a different role in the biofuel industry given that patents will typically be sought for specific technology components, for example for. improvements. There will be competition amongst such patented products within the industry – and with alternative energy sources. This could drive licensing fees down.

- Trade and tariff barriers and other restrictions with agricultural products pose greater threats to access of developing countries to new biofuels technology than IPRs.

c) Other observations regarding equitable cost–benefit distribution

- Whether there is equitable distribution of costs and benefits will be variable and depend on which new biofuels approach is being considered, as well as the scale and ownership of the production facilities. For instance, new biofuels production need not be as centralised as fossil fuel production; decentralisation could benefit small producers.

- Governance at both the local and national levels will matter. For instance, the formation of farmer cooperatives or unions could ensure more equitable arrangements.

d) Suggestions for governance for distributing benefits to farmers and workers

- Emphasis should be placed on ensuring that biofuels development actively involves all stakeholders.
- Local benefits should be a central requirement of new biofuels production. For example, there should be access to affordable energy in the region before any export is considered, and there could be initiatives to employ a local workforce.
- Countries in the global South should be assisted to establish a green economy, as well as defences against climate change and diminishing quantities of readily available oil ('peak oil').

Specific potential measures to support equitable cost–benefit distribution

- Grants could be made available to farmers and growers – in both developed and developing countries – to enable their participation in value creation.
- Investment could be directed towards technology options that would facilitate the participation of farmers and workers globally. For example, decentralised varied production can mean greater social benefits at the local level.
- There could be promotion of technology transfer to enable participation by developing countries. There also could be opportunities for sharing best practice as the industry develops.
- New biofuels technologies that minimise environmental and socio-economic impacts of biofuels could be made freely available, especially to developing countries.
- In the developing world, small-scale farmers and workers could be protected in large-scale production by participatory schemes, e.g. shares, minimum price regulations etc.
- To empower developing world farmers in their relationships with biofuels distillers, farmer alliances could be established or promoted, and the use of multi-option crops adopted.
- Public–private partnerships (PPPs) could provide investment for large-scale demonstration of technologies developed for the production of new biofuels and this could lead to sharing of the rewards.
- Policy makers should ensure that any sustainability requirements do not unnecessarily (i.e. without significant benefit to the environment or people) restrict producers.

e) Suggestions for governance for intellectual property and access

- It is important that companies do not hinder development and use of new biofuels technologies by the overprotective use of IPRs. Developing countries that own IP behind organisms such as plant crops should similarly also not hinder progress.
- It is likely that much of the new biofuels industry will rely financially on licensing of IPRs. To forge a meaningful industry, robust protection of IPRs will be necessary.

Specific potential measures

- The International Treaty on Plant Genetic Resources for Food and Agriculture and its Multilateral System on Access and Benefit-Sharing focuses on food and feed crops of importance to food security. A similar system could be designed for biofuels feedstock.
- International organisations could hold the patents for technologies for new biofuels to ensure access for all. A two-tier fees system could be established depending on the wealth of the country seeking licence.

- Issues of IP and access should be left to industry to deal with; governments should not play a role here.
- Increased public investment in R&D, e.g. by universities, would help to ensure greater public ownership of socially valuable technology, as well as greater access through appropriate licensing agreements.
- A multi-stakeholder process from the start of R&D would help ensure access. There are already a number of joint industrial ventures designed to co-develop and share IP, to enable access to enzyme technologies and thermochemical processes.

Regarding licensing agreements

- Cross-licensing among firms may permit each to use some of the technological features developed by others in a non-monopolistic way.
- Licensing agreements should include clauses which allow exploitation by other parties if the original commercial partner is not interested in doing so. Such a clause might include a timeframe for commercialisation beyond which the licence would be forfeited.
- Exclusive licensing agreements should be avoided as these can obstruct research. Compulsory licensing with fair license fees would help advance wider R&D.

Regarding developing countries

- Much IP can and should be generated in developing countries where both new biofuels feedstocks and final products will be produced. For example, there could be collaborative generation of IP between developed and developing countries, with IP and any value produced shared.
- A system whereby payment in kind (e.g. knowledge transfer, reduced seed costs etc) replaces monetary transactions could be adopted with developing countries.
- Licensing agreements should contain special provisions for developing countries.

8 Research and development

Consultation respondents were asked which of the new approaches to biofuels looked most promising for commercial and sustainable use, and over what timescales these developments might be commercialised. Some did not respond. Several other respondents explained that they could not respond because they either did not have enough information or were not expert enough to make an assessment. A few respondents commented that it was difficult to predict as it was still at an early stage. Amongst the answers that were submitted, there was a range of opinion and detail, of which broad areas of consensus are presented below. Respondents tended to single out feedstocks, processes or end products rather than whole production chains.

When asked about R&D (what were the current constraints; where should R&D be targeted and by whom) many respondents did not submit answers; a few other respondents indicated that they felt unable to comment. Of those that answered, respondents were divided in opinion regarding constraints that related to current steers for research (for new biofuels and biofuels in general), funding, IPRs and the wider ‘regulatory’ environment. The developing world context was also considered. When asked about where R&D should be directed, many cited specific technological targets for R&D; these are not reproduced here. Some respondents made wider observations, for example, regarding the nature of R&D that should be encouraged or the type of new biofuel that should be developed. A few suggested that R&D should be targeted elsewhere rather than at new biofuels.

a) Current state of research and development

Technologies and feedstocks

- Lignocellulosic biofuels production involving biochemical processes appears promising. This might involve pretreatment of feedstock followed by microbial fermentation or enzymatic digestion. Production of enzymes by the feedstock itself is also a possibility.

- Lignocellulosic biofuels production involving thermochemical technologies, such as pyrolysis and gasification have potential. These might make use of a range of feedstocks including waste, especially in light of increasing urbanisation and large waste outputs.

- ABBs hold promise, including those produced from microalgae or macroalgae (e.g. seaweed). Biofuels can be generated by production of fatty acids which can then be converted to synthetic hydrocarbons.

- Technologies that use waste (e.g. agricultural, forestry and municipal) could play a role in the future. For example, use of agricultural residues would enable farmers to achieve best returns on their investment and yield a low carbon footprint.

- Use of energy crops, including miscanthus or switchgrass, could deliver in terms of cost, availability and GHG emission performance if there is also a reduction in enzyme costs and feedstock yield improvement.

- The use of genetic technologies, e.g. genetic modification and synthetic biology, appear promising.

- The biorefinery concept has potential where thermochemical processing and biochemical processing routes are combined, with a wide range of feedstocks converted into fuels and chemical intermediates.

- The production of biobutanol – a so-called 'drop in fuel' due its compatibility with existing petroleum fuel infrastructure – is also a potential avenue.

Problems

- Thermochemical technologies present problems. For example, pyrolysis generates oil of poor quality, requiring significant and costly pretreatment before it can be upgraded by a conventional refinery. It is also energy intensive. For gasification, biomass is a poor substrate due to its high oxygen content.

- Lignocellulosic biofuels production is associated with high costs, e.g. due to processing costs, which could limit efforts to scale up production. It is also likely to be high-tech, potentially restricting access by small-scale producers in the developed world and populations in developing countries.

- Much ABB production relies economically on the generation of high value co-products. Such a business model cannot be scaled up since this would result in increased levels of co-products, thus reducing their market value.

Timescales for commercialisation

- Estimates for commercialisation of lignocellulosic bioethanol production (produced by biochemical processing) vary between around five to ten years. Technological developments necessary to its production – e.g. production of efficient affordable enzymes – are taking place or are expected broadly in the next five years.

- Estimates for commercialisation of ABBs production are around the ten-year timescale.

- Commercial development will depend on whether subsidies or incentives are available for biofuels production. Sufficient funding and policy infrastructure are also determinants.

Other comments on research and development

- As oil prices rise, new biofuels production may become more feasible.

- The most promising approach will be one that combines optimised aspects along the entire production pathway.

- There is considerable hype regarding the potential of new biofuels, and this may be in order to secure investment.

b) Constraints for research and development for new biofuels

Current direction

- There is an absence of a centralised, for example government-led, programme providing funding or direction. As such, fragmented research initiatives led by industry have arisen. Research has focussed more on biological breakthroughs than scaling up biofuels production. This has delayed the translation of research into commercial applications.

- The breadth of technological pathways was down-sized – and may continue to be so – by the US Government agencies to focus funding on a few possibilities, in the hope of accelerating their development. This prevented serious consideration of other pathways.

- Too much is being invested in R&D for current biofuels rather than new biofuels.

- There has been a broader tendency to concentrate on benefits that can be achieved in the short term, e.g. there has been some focus on using biomass for combined heat and power generation, rather than biofuels production. This is due to a plurality of competing alternative approaches and uncertainty about biofuels.

Funding and the 'regulatory' environment

- There is a lack of public *and* private funding for new biofuels development, attributable to: an absence of policy supporting or promoting R&D activities; a lack of investor confidence in both future political support for biofuels and their economic viability;[571] the current state of the economy.

- Funding is complicated by a fragmentation of research efforts. Additionally, there is competition for investment with other types of technologies, e.g. electric vehicles.

- There is a risk of negative publicity and public opinion partly due to the problems with current biofuels and the lack of clarity or resolution of these. Uncertainty about the public acceptability of new biofuels could stifle funding.

[571] For example, with regards to competing with fossil oil, or the sufficient availability of feedstocks.

- There is uncertainty over European legislation with regards to the release of genetically modified organisms, which could feature in new biofuels production.

- There is insufficient time to develop new biofuels to achieve political commitments by 2020 as set by the Renewable Energy Directive.

Regarding the developing world

- Insufficient capacity, e.g. in terms of skilled personnel, is a problem in developing countries. This might also become a problem in the UK in view of the decline in funding for basic plant sciences as well as a prevailing low esteem of plant sciences in schools.

- There has been a lack of research that would enable translation of basic research to locations worldwide, and there is also little research that would benefit small-scale producers in developing countries.

Other comments on research and development

- R&D for new biofuels receives significant financial and political support; this support should be re-evaluated in the context of their social and environmental consequences, as well as economics.

- R&D is not constrained enough by the requirement to consider the effect of biofuels production on land use, food security and the environment.

Suggestions for governance

- There should be some coordination of research efforts, perhaps at the international level to prevent duplication of efforts.

- The governmental and industry-led groups should help facilitate translation of research into commercial applications, e.g. through connecting researchers and manufacturers.

- Credible, substantiated information on new approaches to biofuels should be made available to the public at large.

- There needs to be an economic or regulatory incentive to use biomass for biofuels.

c) Suggestions for research and development targets

Types of research and development along the production pathway

- There is a need for an integrated approach to biofuels R&D that considers the entire production pathway, from basic research to scaling-up production.

- Cross-disciplinary research – e.g. biological, chemical sciences, agronomy, ecology etc. – should be targeted through policy and funding.

- More R&D should focus on optimising downstream systems, e.g. generating greater value from biorefineries.

- Focus should be given to integrating production systems into existing societal frameworks, e.g. feed, materials, paper production systems.

- R&D will be necessary to assist in the transition from a society widely dependent on petroleum-based fuels to biofuels, e.g. in terms of increasing efficiency; engine design; infrastructure for distribution and storage.

- There is need for constant review of R&D targets since it is unclear which approach will be most effective. Evaluation should be evidence-based and could consider LCA, transferability etc.

- Improved modelling and analytical methods are necessary. LCA research should be prioritised, with LCA including energy gains, GHG emissions, environmental and social impacts and considering the molecule from 'field to tank'.

- R&D should be directed towards achieving objectives, rather than at technologies.

Types of new biofuels

- R&D should be directed towards:

a increasing utilisable biomass per unit or land;

b biofuels derived from wastes;

c lignocellulosic biofuels derived from mixed biomass streams;

d biofuel produced from new sources such as algae;

e new biofuels based on competitive and efficient use of inputs, e.g. biomass and energy inputs;

f 'entry-level' feedstocks that would enable the transition from traditional agriculture to production of new biofuel feedstock;

g approaches that are not reliant on subsidies to be economic;

h producing fuels other than bioethanol and biobutanol and fuels intended for aviation;

i new biofuels derived from feedstocks that can be easily grown by marginalised farmer groups in developing countries; and

j new biofuels based on more decentralised, small-scale production.

d) What should the decision-making process be like?

- The decision-making process should be more transparent. Many stakeholders should be consulted on their views, e.g. developers, vehicle manufacturers, policy experts, the public, non-governmental organisations.

- Some stakeholders should have greater say, e.g. wider society; or industry and end-users.

- There should be international consultation to ensure that the interests of different states and populations are recognised equitably. There should be international agreements to this end.

- In relation to publicly-funded research, industry and academics should be brought together to identify the most promising route.

Who should decide?

- Government should provide a policy background to encourage biofuels development. Targets could be set, allowing industry and other bottom-up initiatives the freedom to develop solutions.

- Strategy needs to be decided by a steering body representing and reconciling the views of different stakeholders, such as academics, biomass users, producers, and Government.

- The market will decide which developments are pursued, but guidance from responsible environmental agencies will be needed.
- Government should fund and direct fundamental science *and* its commercial implementation.
- The private sector should finance and direct research aimed at scaling up new biofuels production. Their involvement should be facilitated by Government.

9 Investment

When asked about where new biofuels investment should be directed and who should invest, many respondents did not respond; one respondent commented that they felt unable to answer the question. Of those that did respond, several described types of new biofuels that should be invested in (e.g. should not compete with food). A few respondents mentioned specific targets for investment. Several respondents believed that the public sector, private sector or PPPs each had a role to play in investing. There was some differentiation as to where their respective investments should be targeted. Attributes of public, private or PPP investment were described.

a) Investment targets

- Investment should be directed towards new biofuels that reduce the impact of human activity on climate change, especially since climate change mitigation is a driver for biofuels development.
- There should be investment in new biofuels that do not have the negative consequences seen with current biofuels, such as large-scale land use change, or competition with food.
- New biofuels that are compatible with rural development (e.g. facilitate the participation of farmers) are also an investment target.
- Small-scale and decentralised production should be prioritised as these are likely to be more sustainable.

b) Who should invest?

- The public sector should invest in the transfer of technology to the developing world.
- Investment in production that benefits small-scale farmers is more likely to be provided by the public sector than the private sector.
- In the developing world, both the public sector and private sector have a more limited capacity to invest; PPPs represent a way forward.
- PPPs have a role in translating innovations into products and getting the product to the market. PPPs should invest in the large-scale demonstration of technologies.
- The private sector could invest in R&D that may be so specialised as to be only relevant to their processes.
- It is likely that the private sector will invest increasingly in R&D, thus taking over from public financing, as commercial value is established.

Attributes of public, private or PPP investment

- Public investment would help to ensure that technological developments are public and capable of being transferred to other developers and countries.

- The provision of public or PPP investment would enable the provision of production pathways that are economically *and* socially sustainable, in contrast to industry where outcomes may be aimed more towards economic viability.

- Private or PPP investment are most efficient in delivering outcomes.

Other comments on investment

- There should be investment from international multilateral financial bodies.

- There is a need for coordination of investment to avoid duplication of efforts.

- It is important to align investment in biofuels production with development and poverty reduction strategies.

- It is wrong to encourage some developing countries' governments to invest in biofuels production. The public sector here is already limited financially and historically, biofuels production has not benefitted the poor owing in part to differing state capacities and difficulties in implementing production and/or enabling use.

10 Issues of policy

Respondents were given the opportunity to indicate policy issues concerning new biofuels. Many did not respond, and one respondent observed that they felt unable to comment. Those that did respond described issues of policy already mentioned in previous analyses, e.g. relating to food, environmental sustainability etc., and these are not reproduced here. Support policies for biofuels in general were discussed, and these were seen broadly as problematic. Regulatory policies such as certification schemes also drew concern. Such issues were believed to relate to new biofuels as well, since these were subject to such policies or were likely to be so in the future.

a) Issues regarding biofuels support policies

- Targets and subsidies have been effective in stimulating rapid expansion of biofuels production but with little oversight for sustainability. Environmental and social harms have been incurred as a result.

- The use of such 'unconditional' biofuels support policies has made all current biofuels economically competitive, and has thus to some extent limited the drive to develop new biofuels that are more cost-effective and sustainable.

- Smaller producers do not necessarily benefit from biofuels support policies. For example, financial incentives provided at the point of duty (i.e. when the Government taxes imports or exports) are paid to the large oil companies involved in distribution, leaving smaller producers to negotiate their share.

- In policy, the economic and energy security interests of major developed countries have outweighed consideration of environmental, food security and poverty reduction issues. Also, in general, there is little consultation by policy makers with social scientists who are studying the harms associated with biofuels production.

- An industry for new biofuels requires large investments of time and money. A policy framework to develop confidence for investment is needed.

- Policies that support specific new biofuels technologies rather than goals (e.g. lower GHG emissions) risk not achieving the maximum benefits possible. At worse, given the difficulty in predicting 'winners', an inefficient technology could be supported.

b) Issues regarding biofuels regulatory policies

- Application of certification schemes for sustainability is currently voluntary. However, this can mean low uptake and a reduced drive to produce sustainable biofuels. There is thus a question of whether such schemes should be mandatory.

- There is limited consensus as to how to evaluate biofuels production pathways. There is a need to develop protocols that are standardised, agreed upon and evidence-based.

- Whilst states recognise the importance of developing sustainable biofuels, there is a lack of political will for their production.

11 Suggestions for governance

Respondents were invited to suggest the most effective policies for promoting or regulating new biofuels development. Many did not respond, with a few of these stating that they had already made suggestions in previous submissions. Another respondent said that they felt unable to comment. Suggestions relating to food security, environmental sustainability etc. are not reproduced here but are in previous analyses. Recommendations are grouped broadly into market-based mechanisms and other types of policy intervention. There were proposals across the production pathway and for wider society, e.g. policy makers and the public were considered. Respondents made some suggestions that were relevant to biofuels in general; these points are presented here as they too have a bearing on the promotion or regulation of new biofuels. Recommendations were also made as to how 'sustainable' biofuels could be governed; rather than new biofuels.

a) Promoting biofuels in general

- Mechanisms to enable use are important. To this end, it could be useful to support collaboration between developers and end-users. Uptake might also be promoted through providing consumer incentives.

- Creation of a 'level playing field' for all agricultural products would prevent certification schemes for biofuels serving as a penalty to the industry.

- Effective regulation would do much to build consumer and market confidence in the sustainability of biofuels, and could promote biofuel development.

b) Promoting new biofuels

Market-based mechanisms

- In the UK, production of biofuels in general has been promoted through the provision of duty rebates and the existence of the Renewable Transport Fuels Obligation. New biofuels production could be specifically and directly promoted by provision of capital grants. A system which rewards their production could also be adopted, e.g. including duty rebates, tax concessions of certain processes etc.

- Mandated markets for new biofuels could be effective. The US requires that an increasing part of its renewable fuel target comprise 'advanced' biofuel. Such markets might also be established at European level or a national level.

- Indirect promotion could be achieved through providing financial incentives for biofuels production which are *goal* specific (e.g. produce lower GHG emissions), rather than being aimed at specific technologies. The scale of the reward could be proportional to the outcome.

- The wider introduction in society of carbon credits (where value has been assigned to reducing or offsetting GHG emissions), incentives for recycling waste, or taxation of GHGs could help promote new biofuels development.

- New biofuels could be associated with increased capital costs, e.g. due to implementation of good practices. Any biofuels certified as sustainable might similarly have additional costs, e.g. due to auditing procedures. These reduce the competitiveness of producers; therefore widespread market commitment is required to promote their production, e.g. where consumers are willing to pay higher prices, companies commit to sourcing only new biofuels, or fossil fuels are taxed to reflect their associated harms.

- Market measures should have an end-date – or a clause to enable their phasing out – to avoid hindering wider development. Where financial support is given, this should be limited as unlimited support tends to encourage inefficiencies.

Other mechanisms

- Political will is important. There is a role for multilateral international organisations, such as the Organisation for Economic Co-operation and Development or the Food and Agriculture Organization of the United Nations, to promote new biofuels. Balanced public engagement, as well as thoughtful engagement with the media for dissemination of information would help both to foster political will as well as stimulate their use.

- Encouraging teaching in new biofuels, for example by engaging with education institutions, would promote their development.

- Appropriate facilities to translate work from the laboratory to large-scale production (a process analogous to translational medicine) are required.

- It is important to establish new necessary infrastructure across the new biofuels production pathway, e.g. to enable the transport of agricultural, forestry or municipal wastes to points of biofuels production.

- Implementation of the Renewable Energy Directive could support new biofuels in Member States. The use of policy to regulate 'biofuels' (e.g. requiring certification scheme use) would drive the development of sustainable biofuels, which could comprise new biofuels.

c) Regulating biofuels in general

- It is not effective to introduce targets and provide incentives for biofuels production first and then to devise regulation. Oversight is required both before and after targets have been set.

- Trade barriers and tariffs could be reviewed to enable the import of biofuels from countries where there is sustainable biofuels production, e.g. involving sustainable land use through the use of zoning.

- Other trade measures could be beneficial such as World Trade Organization agreements on agriculture, technology transfer and IPRs, liberalisation of environmental goods and service, and norms on subsidies.

- Bans, e.g. import restrictions, to stop unsustainable biomass use could be used.

d) Regulating new biofuels

- If incentives were to be introduced to promote new biofuels production specifically, these have to be scaled in proportion to their success. For example, tax concessions for processes that achieve GHG savings would be dependent on how effective those processes were. Financial incentives could even be cancelled.
- The provision of any direct incentives should be reviewed and coupled with funding for further research.
- Sustainability rules for best practice which are evidence-based could be adopted.
- Certification schemes that are standardised, evidence-based and have broad consensus could be used.
- Many initiatives designed to assure the sustainability of agricultural commodities are currently industry led, e.g. the 'roundtables'. Uptake has been a problem in some instances. This raises the question of whether Government should take a stronger role in regulating against harms. Mandatory thresholds could be enforced.
- There is a place for consultation with multiple sectors (including representatives from the rural poor) on an international scale, organised by a multilateral body.
- A halt to and thorough review of current policies is required before policies are enacted in relation to large-scale production of new biofuels.

e) Other comments on governance

- There should be consideration whether biofuels production on an industrial scale should be banned.
- It is necessary to agree a hierarchy for using biomass before any policies are established. Whilst biomass may be used more efficiently to generate heat and/or power, there are currently other possibilities for this. Biofuels production could take primacy since it is currently the only viable substitute for petroleum-based fuels.
- Any regulatory framework for biofuels production, e.g. a certification scheme considering impacts of land use, should be applied for all agricultural production and other forms of energy production. This avoids trade distortion.
- There is a need for integrated policy across the production pathway which examines and addresses policy conflicts. Biofuels also should not be considered in isolation of other energy sources and energy efficiency measures.
- Rapid and effective evaluation of new approaches with regards to their sustainability are important to avoid slowing R&D and limiting innovation.
- Policies alone will not be enough. There needs to be effective actions associated with them based on understanding the real challenges. Indeed, location-based approaches will be necessary.

List of respondents

There were 43 responses from organisations and 50 responses from individuals; 13 respondents (organisations and individuals) requested not to be listed.

Organisations

1. Advanced Biofuels USA
2. Avantium
3. Bahamas Green Energy Solutions
4. Biofuelwatch
5. Biotechnology and Biological Sciences Research Council Sustainable Bioenergy Centre (BSBEC)
6. BP
7. Delft University of Technology, Kluyver Centre for Genomics of Industrial Fermentation, Section BTS
8. EcoNexus
9. ESRC Centre for Genomics in Society
10. EuropaBio
11. Faculty of Science, University of East Anglia
12. Food Not Fuel
13. Friends of the Earth England, Wales and Northern Ireland
14. Gasification Australia
15. GeneWatch UK
16. INRA, CEPIA division: Michael O'Donohue (Research Director, Deputy Head of INRA Department CEPIA), Thierry Chardot (Research Director, Department CEPIA)
17. Institute for Science, Ethics and Innovation
18. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
19. International Union for the Protection of New Varieties of Plants (UPOV)
20. NNFCC
21. Novozymes
22. Rothamsted Research
23. Royal Society of Chemistry
24. Society for General Microbiology
25. spaice
26. Swan Institute, Newcastle University
27. The Linnean Society of London
28. The Society of Biology
29. United Nations Office of the High Commissioner for Human Rights (OHCHR)
30. University of Cambridge Bioenergy Initiative
31. Vertigo SDC Limited
32. Volkswagen Aktiengesellschaff, Group Research, Environmental Affairs
33. World Business Council for Sustainable Development
34. World Trade Institute
35. Worldwatch Institute
36. Geoff Bell, CEO Microbiogen
37. Michael Hammer, One World Trust
38. Simon Graham, Environmental Strategist at Commercial Group
39. Tim Rice, ActionAid

Individuals

1. Anil Hira
2. Ben Phalan
3. Bernardo Ospina
4. C. Ford Runge, University of Minnesota

5. Daniel Asin
6. David Alan Walker
7. Dennis Baker
8. Dr Ben Richardson
9. Dr Gordon Allison, University of Aberystwyth
10. Dr Joerg A Priess, Helmholtz Centre for Environmental Research, Germany
11. Dr Joachim H Spangenberg, Sustainable Europe Research Institute SERI Germany e.V.
12. Dr Magni Bjarnason
13. Dr Matthew Struebig
14. Dr N Baghaei-Yazdi
15. Dr Paul Upham, Manchester Institute of Innovation Research and Tyndall Centre Manchester, University of Manchester
16. Dr Peter J Leggo
17. Dr Thomas Molony, Centre of African Studies, University of Edinburgh
18. James Palmer
19. Jason Hill
20. Jeffrey A McNeely
21. Jonathan Gressel
22. Kyriakos Maniatis
23. Nazia Habib-Mintz
24. P Wadsworth
25. Pete Smith, University of Aberdeen
26. Peter Phillips, Johnson Shoyama Graduate School of Public Policy, University of Saskatchewan, Principal Investigator on Genome Canada funded project Value Generation through Genomics (VALGEN), David Castle, Faculty of Arts and Faculty of Law, University of Ottawa, Principal investigator on VALGEN, Stuart Smyth, Department of Bioresource Policy, Business and Economics, University of Saskatchewan, Collaborator on VALGEN, Henry Venema, International Institute for Sustainable Development, Collaborator on Genome Canada funded project Microbial Genomics for Biofuels and Co-products from Biorefining Processes (MGCB2), Matt McCandless, International Institute for Sustainable Development, Researcher on MGCB2, Colleen Christensen, Acting Executive Director of the Feeds Innovation Institute, Network Lead on Agriculture and Agri-Food Canada funded project Feed Opportunities for the Biofuels Industry (FOBI)
27. Phill Piddell
28. Prof Ali Sayigh, WREC
29. Prof DWH Walton
30. Prof Keith Smith
31. Prof R Sylvester-Bradley (ADAS)
32. Prof Stefano Cavallaro, c/o Dipart. Chimica Industriale dell'Università di Messina
33. Professor Jim Lynch
34. Professor Peter Guthrie, University of Cambridge
35. Robert C Brown, Bioeconomy Institute, Iowa State University
36. Robert G Thomas, Church Farm, Colwinstone
37. Robert Henry
38. Saleh M.K. Saleh
39. Sally Gee, Manchester Institute of Innovation Research
40. Simon Gould
41. Sven Sonander

Appendix 3: Working Party members' short biographies

Professor Joyce Tait CBE FRSE FSRA (Chair)

Scientific Adviser to the Innogen Centre (ESRC Centre for Social and Economic Research on Innovation in Genomics), Edinburgh University

Joyce Tait has an interdisciplinary background in natural and social sciences covering life science innovation strategies, governance and regulation, and stakeholder attitudes and influences. Recent appointments include: member, Board of Directors, Scottish Stem Cell Network Ltd; member, Governing Council of the Roslin Institute; member, Scottish Science Advisory Council; member, Scientific and Technical Council of the International Risk Governance Council, Geneva.

Dr Mike Adcock

Director, Master of Laws (LLM) Programme, Durham University

Mike Adcock is an intellectual property lawyer with a background in science. His research focuses on the use of intellectual property for the protection of plants. He is currently acting as consultant on the review and evaluation of the Community Plant Variety Right regulation. Other recent appointments include: co-author, study on intellectual property rights and genetics for the Department of Health; co-author, report on the use of patents by governments commissioned by Health Canada.

Dr Guy C Barker

Director, Genomics Resource Centre, Life Sciences, University of Warwick

Guy Barker's research focuses on genomics and genetics of plants, with special interests in biofuels, biorefining, novel crops, nutrition and sustainable production. Recent appointments include: member, academic advisory panel of the Chemistry Innovation Knowledge Transfer Network; contributor, Industrial Biotechnology, Innovation and Growth Team report; contributor, Sciencewise project on public perceptions to industrial biotechnology.

Professor Simon Caney

Professor in Political Theory, Department of Politics and International Relations and Magdalen College, University of Oxford

Simon Caney works in contemporary political philosophy. He focuses on the application of political philosophy to global politics and has written on global distributive justice, climate change, human rights, sovereignty, global governance, self-determination, and humanitarian intervention. He has recently been awarded an ESRC Climate Change Leadership Fellowship to work on 'Equity and Climate Change'.

Professor Joanna Chataway

Director of Innovation and Technology Policy, RAND Europe; Co-director, Innogen Centre, Open University

Joanna Chataway has an interdisciplinary background in innovation and technology policy studies and international development. Her research and consultancy experience includes work on science and technology capacity building, North-South Public Private Partnerships, innovation and development. She has conducted research for a broad range of national and international agencies, funding bodies and government departments.

Professor Robin Gill

Professor of Applied Theology, University of Kent and Council Member

Robin Gill was the first holder, in turn, of the William Leech Professorial Research Fellowship in Applied Theology at Newcastle University and of the Michael Ramsey Chair of Modern Theology at Kent. Appointments include: member, British Medical Association Medical Ethics Committee; member, Medical Research Council Stem Cell Bank Steering Committee; former chair, Archbishop of Canterbury's Medical Ethics Advisory Group; honorary canon of Canterbury Cathedral.

Professor Jon Hutton

Director, United Nations Environment Programme – World Conservation Monitoring Centre (UNEP-WCMC)

Jon Hutton is Director of the UNEP-WCMC, the UN's specialist biodiversity assessment centre based in Cambridge. He has a background in biodiversity science, rural development and international policy and more than 20 years experience working in wildlife conservation in Africa. He is a Senior Member of Hughes Hall, Cambridge, and Honorary Professor of Sustainable Resource Management at the University of Kent.

Professor Ottoline Leyser CBE FRS

Professor of Plant Development and Associate Director of the Sainsbury Laboratory, Cambridge University, and Council Member

Ottoline Leyser is a plant developmental geneticist working on the hormonal control of shoot branching, and its role in the environmental control of development. Appointments include: member, Strategy Advisory Board of the BBSRC and chair of its Bioscience Skills and Careers Strategy panel; co-editor in chief, Current Opinion in Plant Biology; deputy chair, Athena Forum; Gatsby Plant Science Advisor.

Dr Nigel Mortimer

Managing Director, North Energy Associates Ltd, Sheffield

Nigel Mortimer has a background in physics and energy technologies and energy and environmental research. He is a practitioner of life cycle assessment which he applies to greenhouse gas emission calculations of a variety of products, including biofuels. Prior to his current post, he held the Chair in Sustainable Energy Development at Sheffield Hallam University, where he was also the Head of the Resources Research Unit.

Professor Christine Raines

Professor in Plant Biology, University of Essex

Christine Raines is a plant molecular biologist. She has a background in photosynthesis with a focus on improving plant yield. She has led or co-led several BBSRC and EU projects on plant metabolism and carbon fixation. She is currently Chair of the Society of Experimental Biology, Plant Section and Associate Editor for the Journal of Experimental Biology.

Mr Ian Smale

Head of Strategy and Policy, BP

Ian Smale has a degree in Geology from Exeter University and attended the Harvard Business School Programme for Management Development in 1996. Prior to his current post, he held a variety of business executive and corporate finance leadership positions at BP, in the UK, Tunisia, Brazil, Singapore, the Netherlands and South Africa. He is currently a non-executive director of the National Nuclear Laboratory.

Professor Jim Watson

Director, Sussex Energy Group, Science and Technology Policy Research Unit (SPRU), University of Sussex; and Research Fellow, Tyndall Centre for Climate Change Research

Jim Watson's research focuses on energy, climate change and innovation policies. Appointments include: chair, British Institute for Energy Economics; co-leader, ESRC/EPSRC research cluster: Energy Security in a Multipolar World; member, IPPR New Era Economics panel; lead expert, Foresight project on Sustainable Energy Management and the Built Environment; specialist adviser, House of Commons Environment, Food and Rural Affairs Committee.

Glossary

Access and benefit-sharing system: a system regulating both access to (genetic) resources and the distribution of benefits arising from the use of these.

Additional land: land that is unsuitable for food agriculture which can therefore be used without impacting on food production.

Advanced plant breeding strategy: a type of plant breeding strategy in which the genetic basis of a trait is screened for in the progeny of a cross using a lab-based test. This saves time and labour compared with *conventional plant breeding*. There are two types of advanced plant breeding strategy: *marker-assisted breeding* and *genomics-assisted breeding*.

Algal-based biofuels: biofuels derived from algae. These are sometimes referred to as *third generation biofuels*.

Anaerobic digestion: the process where microorganisms break down biogenic material to produce *biogas*. It can be employed domestically or industrially to produce *biogas* for fuel.

Annex I: a category of parties to the United Nations Framework Convention on Climate Change. Annex I parties includes the industrialised countries that were members of the Organisation for Economic Co-operation and Development in 1992, as well as countries with economies in transition.

Arable land: land that is suitable for crop production.

Biodiversity: short hand for "biological diversity". This is the variability among living organisms from all ecosystems and the ecological complexes of which they are part. It includes diversity within species, between species and of ecosystems.

Biofuels feedstock: any biogenic material that can be converted to biofuels, e.g. crops or animal waste.

Biofuels system: refers to the biofuels production pathway (development, production and use), as well as the policies that led to the establishment of the pathway, and the ethical implications of these policies.

Biogas: a methane-rich gas produced by *anaerobic digestion* which can be compressed to biofuel for transport, or burned for heat/power generation.

Biomass productivity: the rate at which biomass is generated.

Bioprospecting: short hand for "biodiversity prospecting". This describes research that searches methodically for a natural process or product that can be used for commercial application.

Biorefinery: a facility that produces a range of products from biogenic material such as biofuels, chemicals, heat and power, etc.

Bioremediation: the use of biological systems to treat environmental contaminants.

Breeder's exemption: public-interest provision of the *plant variety rights* system, which allows breeders to use protected material to breed new varieties without the authorisation of the *plant variety rights* holder.

C4 photosynthesis: a type of photosynthesis where carbon dioxide is concentrated in specialist cells, allowing it to be fixed more efficiently.

Carbon debt of land conversion: Fargione *et al.* (2008) define this as the amount of carbon dioxide released during the first 50 years of the conversion of natural habitat to cropland.[572]

Carbon neutrality: where the carbon dioxide produced by a process or person is balanced by the amount of carbon dioxide sequestered out of the atmosphere or offset by that process or person.

Carbon sink: anything that absorbs more carbon dioxide from the atmosphere than it releases, e.g. rainforests and oceans.

Carbon stock: the amount of carbon contained within a system.

Cellulolysis: the chemical reaction where the complex carbohydrate cellulose is broken down into simple sugars.

Common good arguments: claims made on the premise that there are goods which we believe all individuals and generations should share equitably in.

Consequential arguments: see *Teleological arguments*.

Conventional plant breeding: a plant breeding strategy where a desirable trait in the progeny of a cross is identified by growing lines of the progeny and testing for that trait. For example, resistance to a fungal strain would be tested for by infecting the various lines with the fungus and identifying which line was less susceptible. This type of breeding strategy is more time- and labour-intensive than *advanced plant breeding strategies*.

Co-firing: of biomass, refers to the combustion of biomass and coal in power plants. Biomass co-firing reduces greenhouse gas (GHG) emissions such as carbon dioxide and sulphur dioxide.

Co-product allocation: a process considered in *life cycle assessment*. It involves the allocation of resources consumed and emissions produced between the co-products.

Cost-effectiveness: a measure of whether something is effective or productive in relation to its cost.

Deontological arguments: those based on the premise of there being a duty to act in a certain way.

Direct land use change: as understood in discussions about biofuels, the conversion of natural land (e.g. forestland, woodland, peatland or wetland) to cropland for biofuels feedstocks.

Dual-use crop: in the context of biofuels, one that may be used to produce both food and fuel.

Ecosystem services: the benefits that can be obtained from ecosystems, including provisioning services such as food; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation and nutrient recycling.

Energy-conversion potential: with regards to a *photosynthetic organism*, the capacity to convert light energy from the sun into chemical energy, i.e. the energy stored in the molecules of the organism.

Energy density: the amount of energy per unit volume.

Energy portfolio: refers to the set of energy sources.

Energy security: the uninterrupted physical availability of energy products on the market, at a price which all consumers can afford.

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[572] Fargione J, Hill J, Tilman D, Polasky S and Hawthorne P (2008) Land clearing and the biofuel carbon debt *Science* **319**: 1235–8.

Fairtrade scheme: a certification scheme run by Fairtrade Labelling Organizations International, which is used to certify products (e.g. bananas, coffee, etc.) as a reflection that the producers have received a better deal and improved terms of trade.

Feedstock: see *Biofuels feedstock*.

Fermentation: carried out by microorganisms in the absence of oxygen, the enzymatic breakdown of organic substances to simpler organic products. For example, sugar is fermented by yeasts to produce alcohol.

First generation biofuels: refers commonly to biofuels that are made from the food parts of food crops, such as sugar cane and oil palm, including bioethanol fermented from sugars and broken-down starch, and biodiesel derived from plant oils. *Biogas* is also known as a first generation biofuel.

Flexible fuel vehicle: a vehicle that is able to run on either petrol or petrol/ethanol blends of up to 85 per cent ethanol (E85).

Food security: referred to by the Rome Declaration on Food Security as: "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life."[573]

Food versus fuel debate: the controversial and ongoing debate as to whether biofuels production competes with food production.

Genetic modification: a process involving the transfer of foreign or synthetic DNA into an organism to introduce a desirable trait. Genetic modification allows the combination of genetic material that would be very difficult or impossible by conventional breeding or mating.

Genomics-assisted breeding: a type of *advanced plant breeding strategy*, this involves screening across the genomes of progeny for the genetic variation associated with a desirable trait.

Global final energy consumption: this is the total amount of energy consumed worldwide. It includes marketed energy sources (e.g. fossil fuel, wind power, etc.) as well as non-marketed energy sources (e.g. wood, waste, etc.).

Global warming potential: a measurement of the potency of GHG emissions in contributing to global warming over a period of time, measured relative to carbon dioxide.

Green collar jobs: jobs in the environmental/ecology sector.

Human rights: rights deemed to belong to any human being – no matter the state or nation to which they belong – and which must be respected equally everywhere in the world.

Idle land: in this report, this refers to agricultural land that is part of a crop rotation programme.

Indirect land use change: a market-driven phenomenon which is thought to occur when existing cropland, e.g. that which is used for corn or wheat production, is used instead for biofuels production. In response to the reduction in the levels of these previously cultivated crops, land elsewhere (e.g. forest or grassland) is converted to cropland, potentially emitting GHGs.

Intellectual property rights: rights protecting property that does not exist in tangible form and is the product of creativity, e.g. inventions, industrial designs, artistic and literary works.

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[573] The Rome Declaration on World Food Security 1996, art 1.

Intergenerational justice: the concept that each generation should act justly with regards to the legitimate interests of future generations.

Land grab: a pejorative term used in reference to the alleged seizing of land in developing countries by companies/governments, with no regard for the rights of the indigenous communities there.

Leakage: see *System leakage*.

Life cycle assessment: an evaluation of the environmental and resource impacts of a process. With regards to biofuels production, this examines those associated with: growing and transporting the *biofuels feedstock*; converting the feedstock to biofuel; and distributing the biofuels for use.

Lignocellulose/ lignocellulosic biomass: the fibrous and inedible parts of a plant which make up the plant cell walls. Lignocellulose comprises sugar polymers and lignin.

Lignocellulosic biofuels: biofuels derived from *lignocellulose*, and therefore the *residues* of food crops, as well as non-food crops. Production involves either biochemical or thermochemical processing of *lignocellulose*.

Marginal land: there is no agreed definition for marginal land; however, it has been commonly used to refer either to land that is unsuitable for food agriculture or land that has a low *carbon stock*.

Marker-assisted breeding: a type of *advanced plant breeding strategy* involving screening the progeny for the gene variant (or genetic variation on a nearby chromosome) for the desirable trait.

Next generation biofuels: used interchangeably in reference to *second generation biofuels*, *third generation biofuels*, *lignocellulosic biofuels* and *algal-based biofuels*.

Nitrous oxide emissions: these can occur following the application of nitrogen fertilisers in crop production. Emissions of nitrous oxide are approximately 300 times more powerful than carbon dioxide emissions in terms of causing global warming.

Oil crunch: where the production capacity of excess crude oil falls to low levels. This is followed by a temporary suspension of crude oil supply which leads to a price spike.

Perennial crops: plants that live for more than two years.

Photosynthetic organisms: organisms using the process photosynthesis, i.e. the light-dependent production of organic molecules from inorganic molecules, where carbon dioxide is converted into energy. Examples include plants, algae and some bacteria.

Phytoremediation: the use of plants to treat environmental problems, such as removing toxins from contaminated soils.

Plant variety rights: rights that may be exercised by breeders to protect new plant varieties they produce except when other breeders exercise the *breeder's exemption*.

Population fragmentation: when a species population becomes fragmented geographically due to the breaking up of its habitat.

Precautionary approach/ principle: there are many different interpretations of the precautionary approach. This report is underlined by a comparative or moderate version that calls for a case-by-case analysis of a development in terms of its risks and benefits, and the costs of its consequences.

Pretreatment: the first step of processing *lignocellulosic biomass* into biofuels. Pretreatment generates intermediates that are denser (thus increasing their transportability) and easier to process (thus reducing processing costs).

Primary agricultural productivity: the productivity of primary agriculture, i.e. activities that are specialised and generally performed on a farm. Examples include animal breeding, harvesting, etc.

Primary forest: a natural forest which has not been disturbed or modified by human activity – such as logging or clearing – and as such contains many mature trees. Primary forests display significant differences in forest structure and/or species compared with those of *secondary forests*.

PróÁlcool: full name Programa Nacional do Álcool. The national alcohol programme launched by the Brazilian Government in 1975.

Public–private partnership: any partnership involving organisations from both the public and private sectors. The involvement of these organisations can vary in terms of their functioning role and contribution of funds.

Recalcitrance of the cell wall: characteristic of the plant cell wall where its components are resistant to microbial and enzyme degradation. This recalcitrance arises through the presence of lignin and needs to be overcome if the sugars present in the cell wall are to be released for biofuels production.

Renewable energy: a type of energy which is not depleted by use.

Residue or waste product: what is left over or remains, for instance following agricultural, forestry and municipal (i.e. relating to a town or district) activities. Examples from agriculture include straw and stover from wheat, barley, etc.

Secondary forest: a forest that has grown naturally following some natural disturbance, such as fire or human activity. Secondary forests display significant differences in forest structure and/or species compared with those of *primary forests*.

Second generation biofuels: refers commonly to biofuels that do not make use of the food parts of food crops (in contrast with *first generation biofuels*). Second generation biofuels are produced using more efficient sources of biomass, as well as more efficient production techniques. Examples include *lignocellulosic biofuels*.

Short rotation coppice: a specialised form of forestry plantation which involves growing trees close together and harvesting these at regular intervals (about every three years).

Stewardship: a philosophical position which holds that human beings act as stewards of the natural world. Within this, human beings have legitimate rights to use the natural world but are simultaneously obligated to protect it for future generations.

Sustainability: the position that some entity or value should be sustained over time.

Syngas: a mixture of hydrogen and carbon monoxide gases, produced as an intermediate in the type of *lignocellulosic biofuels* production which makes use of thermochemical processing.

System leakage: refers in this report to a situation where sustainability standards are applied only to biofuels production, thus meaning that other uses of biomass and agricultural/land practices can occur (or continue to occur) in a non-sustainable manner.

Teleological arguments: also referred to as *consequential arguments*. These take the position that the judgment as regards the morality of an action is based on the consequences of that action.

Third generation biofuels: sometimes used to refer to *algal-based biofuels*.

Total marketed world energy consumption: this refers to the amount of marketed energy consumed worldwide. Fossil fuels are examples of marketed energy sources, whereas non-marketed energy sources include some wood and waste products that are not bought or sold in markets. The latter are used prevalently in developing countries.

Total world delivered energy consumption: this refers to the amount of energy consumed directly (i.e. without any conversion or transformation process) worldwide, as well as the global electricity retail sales (excluding energy losses from the electrical system).

Transesterification: a chemical reaction used in the production of the *first generation biofuel* biodiesel. The reaction involves the mixing of plant oils with sodium hydroxide and either methanol or ethanol to produce fatty acid methyl (or ethyl) ester – i.e. biodiesel.

Trickle-down economics: an economic theory which holds that tax breaks for the wealthy and industry and investment in industry stimulate the economy, and so indirectly benefit the wider population.

These definitions given here have been derived from publicly-available sources.

List of abbreviations

ABB	Algal-based biofuel
ABS	Access and benefit sharing
AD	Anaerobic digestion
AIDS	Acquired immune deficiency syndrome
APBS	Advanced plant breeding strategy
BBSRC	Biotechnology and Biological Sciences Research Council
BSBEC	BBSRC Sustainable Bioenergy Centre
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CCC	UK Committee on Climate Change
CSD	United Nations Commission on Sustainable Development
dLUC	Direct land use change
DNA	Deoxyribonucleic acid
EBI	Energy Biosciences Institute
EC	European Commission
EIBI	European Industrial Bioenergy Initiative
EISA	Energy Independence and Security Act of 2007
EPA	US Environmental Protection Agency
EPAct	Energy Policy Act of 2005
EU	European Union
FAME	Fatty acid methyl ester
FAO	Food and Agriculture Organization of the United Nations
FLO	Fairtrade Labelling Organizations
FTA	Free trade agreement
GATT	General Agreement on Tariffs and Trade
GBP	Pound sterling

GHG	Greenhouse gas
GWP	Global warming potential
HIV	Human immunodeficiency virus
IEA	International Energy Agency
iLUC	Indirect land use change
IP	Intellectual property
IPR	Intellectual property right
LCA	Life cycle assessment
LUC	Land use change
MP	Member of Parliament
MTBE	Methyl *tert*-butyl ether
NCR	Native Customary Right
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PBR	Photobioreactor
PDP	Product-development partnership
PPP	Public–private partnership
RED	Renewable Energy Directive
RFA	UK Renewable Fuels Agency
RFS	Renewable Fuel Standard program
RSB	Roundtable on Sustainable Biofuels
RTFO	Renewable Transport Fuels Obligations
SRC	Short rotation coppice
TBT	Agreement on Technical Barriers to Trade
TRIPs	World Trade Organization Agreement on Trade Related Aspects of Intellectual Property Rights
UDHR	Universal Declaration of Human Rights
UN	United Nations

UNFCCC	United Nations Framework Convention on Climate Change
UPOV	International Union for the Protection of New Varieties of Plants
USD	US dollar
VEETC	Volumetric Ethanol Excise Tax Credit
WTO	World Trade Organization

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